THERMOTRON SYSTEM 10-452

PURCHASED FOR F-14 BURN-IN AES 10-28-74

TRACK PROPERTY No. 46106361

TM No H1421ZA4AABC

SYSTEM F-14

STEVE LENARDS

S2097

MODEL 012003

THERMOTRON

INSTRUCTION MANUAL

INSTR. LAB.

IN THE BEGINNING
THERE IS PRICE

IN THE END,
THERE IS COST

As a businessman, you know there are certain things you would never buy on the basis of price alone.

And probably, way up near the top of that list are environmental facilities.

Thermotron doesn't sell test chambers on price. We sell on the value of experience, services, quality and performance.

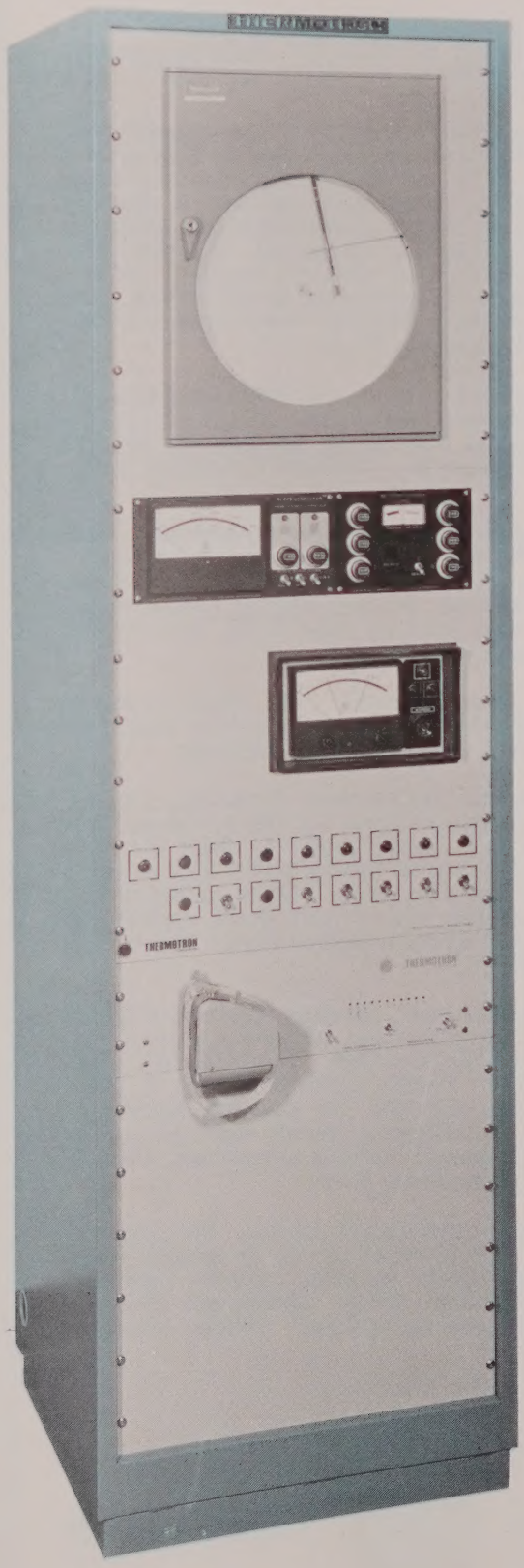
These services and performance are designed to help you prevent and control losses of production and products; and losses are what determine ultimate cost.

That's why we don't just ask for the chance to QUOTE on your business. We want the chance to show you what we can be worth in the long run.

S. F. LENARDS

FEB 10 1975

SR. PROD. ENG.



Program Temperature Control "SYSTEM 11"

master control console with inherently computer compatible controls/designed and built by Thermotron

S. F. LENARDS

FEB 10 1975

SR. PROD. ENG.

WORLD HEADQUARTERS

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highest quality components

solid state circuitry

designed specifically for environmental simulation equipment

manufactured by Thermotron

100 hour pre shipment burn in Q.C. test

(1) Series 452 Honeywell Servoline 12" diameter recorder. Range -87°C. to +190°C., or -125°F. to +375°F.

(1) Thermotron temperature controller. Sub-assembly no. 012003. Bi-directional proportioning of heating and cooling. Range -87°C. to +190°C. Built in out-of-range fail-safe protection. Solid state electronics provides voltage out-puts to remote zero-firing power switching modules, 0-5 V. computer compatible. Includes automatic refrigeration machine time-out function. Adjustment panel includes proportioning band, manual reset cycle time, range limits, deviation meter range and compressor time-out. Accuracy ±¼%.

(1) 6-station temperature set point unit with digital settings. Solid state analog switching system. A 7th set point is built in to provide homing to ambient for fail-safe conditions. Sub system no. – 013006/7. Accuracy ±¼%.

(1) Tape Command —— 8-channel tape programmer. Subsystem no. 1979, 5 amp contacts. System utilizes 1" wide TWX tape. Tape advance 1 minute or 5 minutes, synchronous time base. Features include 1 cycle, repeat cycle, manual tape advance, tape break, run out and misloading fail-safe protection.

(1) Thermocouple sensor, accuracy .1%. Type T copper/constantan unsheathed sensor to minimize sensor lag and error from lead wire thermal conductivity.

(1) Slope generator for temperature transition rate, accuracy ±¼%. Digital set point for rate of rise and rate of temperature fall. Features built in: Built in bypass switch for quick check of setting point, light emitting diodes indicate operating mode. Slope generator permits "Agree" cooling rates or can retard cooling rate for lighter load and slower transition slopes. Sub-system part no. – 013008/9.

(1) Thermotron Productsaver. Sub-system part no. 012005. Provides precision under/over temperature alarm systems. Thermocouple activated. Thermocouple break fail-safe provision. System includes audible & visual alarms. Contacts provided for stopping heating or cooling circuits and activating remote alarm device. Includes relay to de-energize circuits to test item. Factory Mutual approved. Accuracy ±¼%.

(1) Thermotron instrument/control console. Standard 19" relay rack size and prewired to all equipment listed. Includes function control switches, indicator lights and interconnecting cabling. Color: Thermotron blue with contrasting light gray panel faces. Welded steel construction.

OFFICES IN TWENTY ONE CITIES AND SEVEN COUNTRIES

THERMOTRON
CORPORATION

HOW TO SET THE OPERATOR'S CONTROLS

of

TEMPERATURE CONTROLLER 012003

PRELIMINARY INFORMATION

This controller was designed for use on environmental/reliability test equipment. Its temperature range is -125F to +375F. This type of equipment typically cycles between low and high temperature, -65F and +160F, for example. Hence, the controller is designed to operate both heating and cooling equipment.

Several of the Operator's Controls are calibrated in percent insted of degrees F. This is done because the response of the thermocouple is nonlinear. In general,

0% = -125F & 100% = +375F

. . . but 50% does not equal +125F. The temperature corresponding to 50% of span is actually +157.3F. You can see why on the thermocouple millivolts table:

+375F = +8.787mv	†11.793mv = 100%
+157.3F = +2.890mv	† 5.897mv = 50%
–125F = –3.006mv	† 0.000mv = 0%

† = input mv referred to -125F input

As a general rule, 1% = 5 degrees F. Near the low end of the range 1% will be equal to about 7 degrees, and on the high end 1% will be about equal to 4 degrees.

1. INITIAL SET UP

If you're starting from scratch, set the controls as follows:

HEAT P ZONE	–1%
HEAT RESET	0%
HIGH LIMIT	100%
COOL P ZONE	+1%
COOL RESET	0%
LOW LIMIT	0%
PULSE RATE	60PPM
MACH TIME OUT	30Sec
DEV SPAN	±5%

These settings should bring a typical system into the 'ball park'.

Now observe the performance of the system as it runs through its normal operating pattern. Not much can be done to speed up this process, since timing is part of the control problem. For instance, if the system is cold for six hours and then switches to a high temperature, part of the heat up performance will be due to the fact that the chamber liner will still be cold long after the air temperature reaches the high set point. So when setting up the controller, you have to duplicate this situation. Otherwise the performance during actual operation may turn out differantly than the performance during set up.

2. PROPORTIONAL ZONE ADJUSTMENTS

These adjustments control the width of the proportioning zones. The heat proportioning zone extends from the set point to some lower temperature. The cool proportioning zone extends from the set point to some higher temperature.

As the temperature moves through the proportioning zone towards the set point, the heating or cooling action will be throttled down. When the temperature is at the set point, the heating and cooling outputs will be zero. This points out one of the inherant limitations of proportional control action.

Suppose that the set point is +230F, and the heat loss at this high temperature is considerable (insulation leakage, etc.). How can this heat be replaced while holding the temperature at the set point?

With proportioning action alone, it can't. The result is that the termperatur will 'droop' below the set point. Control will be established at the point where the heat added is equal to the heat being lost. If the proportioning zone is five degrees wide and the required heating output is 20%, then the droop will be minus one degree (+229F). If the proportioning zone is twenty-five degrees wide, for this case the droop would be minus five degrees (+225F). This illustrates why the proportioning zones should always be set as narrow as possible.

When the proportioning zones are set TOO WIDE, the result will be that during heat ups and pull downs, the temperature will never reach the set point because the heating and cooling equipment will be throttled too much, too soon. Thereafter, there will be too much droop, and the response to load changes will be poor.

When the zones are set TOO NARROW, overshoot will occur at the ends of heat ups and pull downs. Thereafter, the temperature will probably cycle above and below the set point. This oscillation will slowly dampen out unless the zones are much too narrow, in which case it will continue indefinately. If the system ever does stabilize, small load changes might frequently trigger this same oscillatory control action.

3. RESET ADJUSTMENTS

You have to set the proportional zone adjustments to minimize overshoot and cycling at set point. If this results in too much droop, you can correct this by shifting the proportioning zones so that they overlap the set point. This is done with the reset adjustments.

For example, if the set point is +160F, but the control point is only +157F, turn the heat reset knob to about +.6% (1% = 5F). If the set point is -65F and the control point droops at -60F, set the cool reset at about -1%. This will bring the control point to the set point.

You can also move the proportional zones away from the set point. This you would do if you have trouble with heating and cooling bucking each other at the set point, as sometimes happens in systems which are difficult to control.

For instance, you might set the heat reset at -.2% and the cool reset at +.2%. This would create a dead zone of about 2 degrees with the set point centered in the middle of it. Note that this means that you'll have to live with a one degree droop, unless you can add a one degree 'fudge factor' to the set point.

4. LIMIT ADJUSTMENTS

The limit adjustments provide failsafe action for the controller. Whenever the temperature crosses either the high or low limit, the controller's outputs will all be clamped OFF.

If you want to shorten the controller's range to protect aginst set point tampering, or whatever, you may set these limits closer to your actual operating range. For example, if your lowest temperature is -65F and your highest temperature is +160F, you might set the low limit to -75F and the high limit to +170F. Refering to the % Span Tables:

+170F = 52.7%
- 75F = 7.4%

Realize that these limits are not capable of protecting your system aginst all types of failures. They will protect aginst certain types of controller failures, including open thermocouples, and they can help to protect aginst set point errors and faults. However, if the output of the controller, or something connected to it, should happen to fail in the ON condition, these limits can do nothing to prevent a run-away condition. Therefore, your system should include some redundant device(s) which offer added protection aginst failures of this type. Prior to operating the system you should see to it that such devices are properly set, and that they are in good working order.

5. PULSE RATE ADJUSTMENT

The proportioning action is achieved by controlling the length of time that the cooling and heating are ON during each of a consecutive train of timing intervals. The pulse rate adjustment actually controls the number of intervals per minute.

So far a control is concerned, the faster you pulse the system, the better. However, the maximum mileage on contactors and solenoid valves is measured in mechanical operations, so its not good practice to pulse the system faster than necessary to achieve good control.

To find this point, set the pulse rate at 120PPM and let the system stabilize. Then slow down the pulse rate in small incriments until the temperature just begins to cycle. This is the slowest pulse rate that you will be able to run. This rate might be differant for cooling and heating. If so, set the knob at the faster rate.

6. MACHINE TIME OUT ADJUSTMENT

This circuit controls the operation of the refrigeration equipment so that it does not have to turn on and off as the cooling valve is pulsed.

You may set this knob at 120 seconds. If you want the machinery to turn off faster following periods of cooling operation, shorten the delay as desired. But do not decrease the delay to the point where the machinery cycles on and off during normal cooling operations, since this may shorten the life of the equipment.

7. DEVIATION SPAN ADJUSTMENT

This adjustment controls the sensitivity of the control indicator (deviation meter), if one is provided with the system. When set at ±5%, the meter range is about ±25F, full scale. At 0%, the full scale meter range is about ±.33F. This setting is strictly a matter of preferance.

IN CASE OF DIFFICULTY –

If you have a great deal of trouble in achieving reasonable performance, there's probably nothing wrong with either you or the controller.

Poor control is usually due to late information at the controller. In other words, the controller has to be kept up to date all the time – a few seconds delay can seriously degrade performance.

This means that the response of the sensor has to be fast, and the sensor has to be well located in the air stream. A sheathed sensor won't work because its not fast enough. Likewise, a poorly constructed bare thermocouple will also cause problems. At least four inches of insulation should be stripped away from the junction of the thermocouple, and this entire sensitive length should be well exposed to the air stream. Any clamps or fittings should be at least six inches away from the junction, and preferably loose fitting – not clamped down tightly on the wire. If the sensor is located in a 'dead spot', or shaded by another sensor, this can also appear as poor sensor response.

In test systems, this is usually the problem. Lags associated with the air flow rate do not usually cause problems, except in ducted air supplies which operate at very low exhaust velocity. The response of the heating

and cooling equipment is not usually a factor, except with regard to the initializing of the cooling system when it first turns on after having been off long enough to 'loose its prime'. If this becomes a problem, set the machine time out delay at 120 seconds then, if necessary, increase the cooling proportioning zone.

If you're useing a temperature recorder to monitor control performance, be sure that the recorder is telling the truth prior to readjusting the controller. What looks like 'undershoot', slow response to small load variations or a slow temperature drift, might well be attributable to the recorder and its sensor. The response of the controller, when properly applied and adjusted, is likely to be equal or better than that of an associated temperature recorder. This is especially true if the recorder is equipped with a platinum resistance temperature sensor – which many prefer in the interest of theoretical accuracy. When adjusting the controller, its generally better to monitor the control indicator (deviation meter), than to rely exclusively upon a recorder.

% SPAN TABLES

FOR PRECISION DIGITAL SET POINTS

COPPER VS. COPPER-NICKEL

(COPPER-CONSTANTAN)

TEMPERATURE IN DEGREES F

RANGE -125° TO +375°F

PERCENT OF ABSOLUTE MILLIVOLT SPAN

DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
120	.0070	.0057	.0042	.0028	.0014	.0000						-120
110	.0215	.0199	.0185	.0170	.0156	.0143	.0128	.0114	.0099	.0085	.0070	-110
100	.0360	.0346	.0331	.0316	.0302	.0288	.0272	.0258	.0243	.0229	.0215	-100
90	0510	0495	0480	0465	.0450	0435	.0420	.0405	.0390	.0376	.0360	- 90
80	.0662	.0647	.0632	.0617	.0601	.0586	.0571	.0555	.0540	.0525	.0510	- 80
70	0817	0801	0786	.0770	0755	0739	.0724	0708	.0693	.0678	.0662	- 70
60	.0975	0959	0943	.0928	0912	0895	.0880	0864	.0849	.0833	.0817	- 60
50	.1135	1119	1103	1087	.1071	.1055	.1039	.1023	.1007	.0990	.0975	- 50
40	.1298	.1282	.1266	.1249	.1233	.1217	.1200	.1184	.1168	.1152	.1135	- 40
30	1464	1447	1431	1414	.1397	.1381	1364	.1348	.1331	.1315	.1298	- 30
20	1632	1615	.1598	1581	1565	.1548	1531	.1514	.1497	.1481	1464	- 20
10	1804	1787	1769	1752	1735	1718	1701	1683	1666	.1649	.1632	- 10
0	.1977	.1960	.1942	.1925	.1907	.1890	.1872	.1855	.1838	.1821	.1804	0
0	.1977	.1994	.2012	.2029	.2047	.2065	.2083	.2100	.2117	.2135	.2153	0
10	.2153	2171	2189	2206	2224	2242	.2260	.2278	.2295	.2314	.2332	10
20	2332	2350	.2368	.2385	.2404	.2422	2440	.2458	.2476	.2495	2513	20
30	2513	2530	2549	2568	2585	.2604	.2622	.2641	.2659	2677	2696	30
40	2696	2714	2732	2751	2769	.2788	2806	.2825	.2843	.2862	.2881	40
50	.2881	.2899	2913	2936	2955	.2974	.2992	.3011	.3030	.3048	.3067	50
60	.3067	.3087	.3105	.3124	3143	3161	3181	.3199	3218	.3238	.3256	60
70	.3256	3276	3294	.3314	3332	3352	3371	3390	.3409	.3428	.3448	70
80	3448	3466	3486	3505	3525	.3544	.3563	.3583	3602	3622	.3641	80
90	3641	.3661	3680	3700	.3719	.3739	.3758	.3778	.3797	.3817	.3836	90
100	.3836	3857	3876	.3896	.3915	.3935	.3955	.3974	.3995	.4014	4035	100
110	4035	4054	4074	.4094	.4114	.4134	.4154	.4175	.4194	4214	.4235	110
120	4235	4254	.4275	.4295	4315	.4336	.4356	.4375	4396	.4416	.4437	120
130	4437	4457	4477	.4498	.4518	.4539	.4559	.4580	.4600	.4621	.4641	130
140	4641	.4662	4682	.4703	.4724	.4744	.4765	.4786	.4806	.4827	.4848	140
150	4848	.4869	.4889	.4911	.4931	.4952	.4973	.4994	.5015	.5036	.5057	150
160	5057	.5078	5099	.5120	.5141	.5162	.5184	.5204	.5225	.5246	.5268	160
170	.5268	.5289	.5310	.5331	.5353	.5374	.5396	.5417	.5438	.5459	.5481	170
180	5481	.5502	.5524	.5545	.5567	.5588	.5609	.5631	.5653	.5675	.5696	180
190	5696	.5718	.5739	.5761	.5782	.5804	.5825	.5848	.5870	.5891	.5913	190
200	5913	.5935	.5957	.5978	6000	.6022	.6044	.6066	.6088	.6110	.6132	200
210	.6132	.6154	.6176	.6198	.6220	.6242	.6264	.6287	.6309	.6331	.6353	210
220	.6353	.6375	.6397	.6420	.6442	.6464	.6486	.6509	.6531	.6553	.6576	220
230	6576	.6598	6620	.6643	6665	.6688	.6710	.6733	.6755	.6778	.6801	230
240	.6801	.6823	.6846	.6868	.6891	.6913	.6936	.6958	.6981	.7004	.7027	240
250	.7027	.7049	.7072	.7095	.7118	.7141	.7164	.7186	.7209	.7232	.7255	250
260	.7255	.7278	.7301	.7324	.7347	.7370	.7393	.7415	.7439	.7462	.7485	260
270	.7485	.7508	.7531	.7554	.7577	.7600	.7624	.7647	.7670	.7694	.7716	270
280	.7716	.7740	.7763	.7787	.5520	.7833	.7856	.7880	.7903	.7927	.7950	280
290	.7950	.7973	.7997	.8020	.8044	.8067	.8091	.8114	.8138	.8162	.8185	290
300	.8185	.8209	.8232	.8256	.8279	.8303	.8327	.8351	.8374	.8398	.8422	300
310	.8422	.8446	.8469	.8493	.8517	.8541	.8564	.8588	.8613	.8636	.8660	310
320	.8660	.8684	.8708	.8732	.8756	.8780	.8804	.8828	.8852	.8876	.8900	320
330	.8900	.8924	.8949	.8972	.8997	.9021	.9045	.9069	.9094	.9117	.9142	330
340	9142	9166	9190	.9215	.9239	.9263	.9288	.9311	.9336	.9361	.9385	340
350	9385	9409	9434	.9458	.9483	.9507	.9532	.9557	.9580	.9605	.9629	350
360	9629	9654	9678	.9703	.9728	.9752	.9777	.9802	.9827	.9852	.9876	360
370	9876	9901	9925	.9950	.9975	.9999						370
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F

TYPE T PER ASA C96.1-1971

*CONVERTED FROM ASA TEMP. VS. EMF TABLES (THERMOTRON 1972)

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% SPAN TABLES

FOR PRECISION DIGITAL SET POINTS

COPPER VS. COPPER-NICKEL

(COPPER-CONSTANTAN)

TYPE T

TEMPERATURE IN DEGREES C

RANGE -87°C TO +190°C

PERCENT OF ABSOLUTE MILLIVOLT SPAN

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
- 80	.0185	0159	.0133	0108	0082	0057	0031	.0006				80
70	.0450	.0423	0396	.0370	0343	0316	0290	0264	0237	0211	0185	70
60	.0724	.0696	0668	0641	0613	0586	.0558	.0531	.0504	.0477	.0450	- 60
- 50	.1007	.0978	.0950	.0921	.0893	.0864	.0836	.0808	.0779	.0751	.0724	- 50
40	1298	.1269	1240	1210	1180	1152	1123	1093	1064	1035	1007	40
30	1598	1568	1538	1508	1478	1447	.1418	1387	1358	1328	1298	30
20	1907	1876	1845	1814	1783	1752	1721	1690	1659	1629	1598	20
10	2224	2192	2160	2128	.2096	.2065	.2033	.2001	.1970	.1938	.1907	- 10
0	.2549	.2516	.2483	.2450	.2418	.2385	.2353	.2321	.2288	.2256	.2224	0
0	.2549	.2582	.2615	.2648	2681	.2714	.2747	.2780	.2813	.2846	.2880	0
10	.2880	2913	2947	2981	3014	3048	3082	3116	3150	3184	3218	10
20	3218	3253	3286	3321	.3355	3390	3424	3459	3493	3528	3563	20
30	3563	3598	3633	3668	3703	.3738	.3773	.3809	.3844	.3879	.3915	30
40	.3915	.3950	.3986	.4022	.4058	.4094	.4130	.4166	.4202	.4238	.4274	40
50	4274	4311	4347	4384	4420	4457	4494	4530	4567	4604	4640	50
60	.4640	.4678	4715	4752	4790	4827	4864	4902	4939	4977	.5014	60
70	5014	5053	5090	5128	5166	5203	5242	5280	5318	5357	5395	70
80	5395	5433	5471	5510	5549	5588	5627	5666	5704	5743	5782	80
90	5782	5821	5861	5900	5939	5978	6017	6056	.6096	6136	.6175	90
100	.6175	.6215	6255	6295	.6335	6374	6414	6455	6495	6535	.6575	100
110	6576	6616	6656	.6696	.6737	6778	6818	6859	6900	6941	6981	110
120	.6981	7022	7064	7104	7145	7186	7227	7269	7310	7351	7393	120
130	7393	7434	7476	7517	.7559	.7600	.7643	.7684	.7726	.7768	.7810	130
140	.7810	.7852	.7894	.7936	.7978	.8020	.8062	.8105	.8147	.8190	.8232	140
150	8232	.8275	8318	.8360	.8402	8446	8488	8531	.8575	.8617	.8660	150
160	.8660	8703	8746	8789	8833	8876	8919	8962	9006	9049	9093	160
170	9093	9136	9180	9223	9268	9311	9355	9399	9443	9487	9531	170
180	9531	.9575	9619	.9663	9708	.9752	.9797	.9841	.9885	.9930	.9974	180
190	.9974											190
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

TYPE T PER ASA C96.1 1971

*CONVERTED FROM ASA TEMP. VS. EMF TABLES (THERMOTRON 1972)

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(616) 392 1492 TWX (810) 292 6164

THERMOTRON

REGISTERED T. M. THERMOTRON CORP.

COPPER vs. COPPER-NICKEL

(Copper-Constantan)

TYPE T

Temperature in Degrees F

Reference Junction at 32°F

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
-190	-4.009	-4.023	-4.037	-4.051	-4.065	-4.079	-4.093	-4.107	-4.121	-4.135	-4.149	-190
-180	-3.864	-3.879	-3.894	-3.908	-3.923	-3.937	-3.951	-3.966	-3.980	-3.994	-4.009	-180
-170	-3.717	-3.732	-3.746	-3.761	-3.776	-3.791	-3.806	-3.820	-3.835	-3.850	-3.864	-170
-160	-3.565	-3.580	-3.596	-3.611	-3.626	-3.641	-3.656	-3.671	-3.687	-3.702	-3.717	-160
-150	-3.410	-3.425	-3.441	-3.457	-3.472	-3.488	-3.503	-3.519	-3.534	-3.550	-3.565	-150
-140	-3.251	-3.267	-3.283	-3.299	-3.315	-3.331	-3.347	-3.362	-3.378	-3.394	-3.410	-140
-130	-3.089	-3.105	-3.121	-3.138	-3.154	-3.170	-3.186	-3.203	-3.219	-3.235	-3.251	-130
-120	-2.923	-2.939	-2.956	-2.973	-2.989	-3.006	-3.023	-3.039	-3.056	-3.072	-3.089	-120
-110	-2.753	-2.771	-2.788	-2.805	-2.822	-2.838	-2.855	-2.872	-2.889	-2.906	-2.923	-110
-100	-2.581	-2.598	-2.616	-2.633	-2.650	-2.667	-2.685	-2.702	-2.719	-2.736	-2.753	-100
-90	-2.405	-2.422	-2.440	-2.458	-2.475	-2.493	-2.511	-2.528	-2.546	-2.563	-2.581	-90
-80	-2.225	-2.243	-2.261	-2.279	-2.297	-2.315	-2.333	-2.351	-2.369	-2.387	-2.405	-80
-70	-2.042	-2.061	-2.079	-2.098	-2.116	-2.134	-2.152	-2.171	-2.189	-2.207	-2.225	-70
-60	-1.856	-1.875	-1.894	-1.912	-1.931	-1.950	-1.968	-1.987	-2.005	-2.024	-2.042	-60
-50	-1.667	-1.686	-1.705	-1.724	-1.743	-1.762	-1.781	-1.800	-1.819	-1.838	-1.856	-50
-40	-1.475	-1.494	-1.513	-1.533	-1.552	-1.571	-1.591	-1.610	-1.629	-1.648	-1.667	-40
-30	-1.279	-1.299	-1.319	-1.338	-1.358	-1.377	-1.397	-1.416	-1.436	-1.455	-1.475	-30
-20	-1.081	-1.101	-1.121	-1.141	-1.160	-1.180	-1.200	-1.220	-1.240	-1.260	-1.279	-20
-10	-0.879	-0.899	-0.920	-0.940	-0.960	-0.980	-1.000	-1.021	-1.041	-1.061	-1.081	-10
0	-0.674	-0.695	-0.716	-0.736	-0.757	-0.777	-0.798	-0.818	-0.838	-0.859	-0.879	0
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
0	-0.674	-0.654	-0.633	-0.613	-0.592	-0.571	-0.550	-0.529	-0.509	-0.488	-0.467	0
10	-0.467	-0.446	-0.425	-0.404	-0.383	-0.362	-0.341	-0.320	-0.299	-0.277	-0.256	10
20	-0.256	-0.235	-0.214	-0.193	-0.171	-0.150	-0.129	-0.107	-0.086	-0.064	-0.043	20
30	-0.043	-0.022	0.000	0.022	0.043	0.065	0.086	0.108	0.130	0.151	0.173	30
40	0.173	0.195	0.216	0.238	0.260	0.282	0.303	0.325	0.347	0.369	0.391	40
50	0.391	0.413	0.435	0.457	0.479	0.501	0.523	0.545	0.567	0.589	0.611	50
60	0.611	0.634	0.656	0.678	0.700	0.722	0.745	0.767	0.789	0.812	0.834	60
70	0.834	0.857	0.879	0.902	0.924	0.947	0.969	0.992	1.014	1.037	1.060	70
80	1.060	1.082	1.105	1.128	1.151	1.173	1.196	1.219	1.242	1.265	1.288	80
90	1.288	1.311	1.334	1.357	1.380	1.403	1.426	1.449	1.472	1.495	1.518	90
100	1.518	1.542	1.565	1.588	1.611	1.635	1.658	1.681	1.705	1.728	1.752	100
110	1.752	1.775	1.799	1.822	1.846	1.869	1.893	1.917	1.940	1.964	1.988	110
120	1.988	2.011	2.035	2.059	2.083	2.107	2.131	2.154	2.178	2.202	2.226	120
130	2.226	2.250	2.274	2.298	2.322	2.347	2.371	2.395	2.419	2.443	2.467	130
140	2.467	2.492	2.516	2.540	2.565	2.589	2.613	2.638	2.662	2.687	2.711	140
150	2.711	2.736	2.760	2.785	2.809	2.834	2.859	2.883	2.908	2.933	2.958	150
160	2.958	2.982	3.007	3.032	3.057	3.082	3.107	3.131	3.156	3.181	3.206	160
170	3.206	3.231	3.256	3.281	3.307	3.332	3.357	3.382	3.407	3.432	3.458	170
180	3.458	3.483	3.508	3.533	3.559	3.584	3.609	3.635	3.660	3.686	3.711	180
190	3.711	3.737	3.762	3.788	3.813	3.839	3.864	3.890	3.916	3.941	3.967	190
200	3.967	3.993	4.019	4.044	4.070	4.096	4.122	4.148	4.174	4.199	4.225	200
210	4.225	4.251	4.277	4.303	4.329	4.355	4.381	4.408	4.434	4.460	4.486	210
220	4.486	4.512	4.538	4.565	4.591	4.617	4.643	4.670	4.696	4.722	4.749	220
230	4.749	4.775	4.801	4.828	4.854	4.881	4.907	4.934	4.960	4.987	5.014	230
240	5.014	5.040	5.067	5.093	5.120	5.147	5.174	5.200	5.227	5.254	5.281	240
250	5.281	5.307	5.334	5.361	5.388	5.415	5.442	5.469	5.496	5.523	5.550	250
260	5.550	5.577	5.604	5.631	5.658	5.685	5.712	5.739	5.767	5.794	5.821	260
270	5.821	5.848	5.875	5.903	5.930	5.957	5.985	6.012	6.039	6.067	6.094	270
280	6.094	6.122	6.149	6.177	6.204	6.232	6.259	6.287	6.314	6.342	6.369	280
290	6.369	6.397	6.425	6.452	6.480	6.508	6.536	6.563	6.591	6.619	6.647	290
300	6.647	6.675	6.702	6.730	6.758	6.786	6.814	6.842	6.870	6.898	6.926	300
310	6.926	6.954	6.982	7.010	7.038	7.066	7.094	7.122	7.151	7.179	7.207	310
320	7.207	7.235	7.263	7.292	7.320	7.348	7.377	7.405	7.433	7.462	7.490	320
330	7.490	7.518	7.547	7.575	7.604	7.632	7.661	7.689	7.718	7.746	7.775	330
340	7.775	7.804	7.832	7.861	7.889	7.918	7.947	7.975	8.004	8.033	8.062	340
350	8.062	8.090	8.119	8.148	8.177	8.206	8.235	8.264	8.292	8.321	8.350	350
360	8.350	8.379	8.408	8.437	8.466	8.495	8.524	8.553	8.583	8.612	8.641	360
370	8.641	8.670	8.699	8.728	8.757	8.787	8.816	8.845	8.874	8.904	8.933	370
380	8.933	8.962	8.992	9.021	9.050	9.080	9.109	9.139	9.168	9.198	9.227	380
390	9.227	9.257	9.286	9.316	9.345	9.375	9.404	9.434	9.464	9.493	9.523	390
400	9.523	9.553	9.582	9.612	9.642	9.671	9.701	9.731	9.761	9.791	9.820	400
410	9.820	9.850	9.880	9.910	9.940	9.970	10.000	10.030	10.060	10.090	10.120	410
420	10.120	10.150	10.180	10.210	10.240	10.270	10.300	10.330	10.360	10.390	10.420	420
430	10.420	10.451	10.481	10.511	10.541	10.572	10.602	10.632	10.662	10.693	10.723	430
440	10.723	10.753	10.784	10.814	10.845	10.875	10.905	10.936	10.966	10.997	11.027	440
450	11.027	11.058	11.088	11.119	11.149	11.180	11.211	11.241	11.272	11.302	11.333	450
460	11.333	11.364	11.394	11.425	11.456	11.487	11.517	11.548	11.579	11.610	11.640	460
470	11.640	11.671	11.702	11.733	11.764	11.795	11.826	11.856	11.887	11.918	11.949	470
480	11.949	11.980	12.011	12.042	12.073	12.104	12.135	12.166	12.198	12.229	12.260	480
490	12.260	12.291	12.322	12.353	12.384	12.416	12.447	12.478	12.509	12.540	12.572	490
500	12.572	12.603	12.634	12.666	12.697	12.728	12.760	12.791	12.822	12.854	12.885	500
510	12.885	12.917	12.948	12.979	13.011	13.042	13.074	13.105	13.137	13.168	13.200	510
520	13.200	13.232	13.263	13.295	13.326	13.358	13.390	13.421	13.453	13.485	13.516	520
530	13.516	13.548	13.580	13.611	13.643	13.675	13.707	13.739	13.770	13.802	13.834	530
540	13.834	13.866	13.898	13.930	13.961	13.993	14.025	14.057	14.089	14.121	14.153	540
550	14.153	14.185	14.217	14.249	14.281	14.313	14.345	14.377	14.409	14.441	14.474	550
560	14.474	14.506	14.538	14.570	14.602	14.634	14.666	14.699	14.731	14.763	14.795	560
570	14.795	14.828	14.860	14.892	14.924	14.957	14.989	15.021	15.054	15.086	15.118	570
580	15.118	15.151	15.183	15.216	15.248	15.280	15.313	15.345	15.378	15.410	15.443	580
590	15.443	15.475	15.508	15.540	15.573	15.605	15.638	15.671	15.703	15.736	15.769	590
600	15.769	15.801	15.834	15.866	15.899	15.932	15.965	15.997	16.030	16.063	16.096	600
610	16.096	16.128	16.161	16.194	16.227	16.259	16.292	16.325	16.358	16.391	16.424	610
620	16.424	16.457	16.490	16.523	16.555	16.588	16.621	16.654	16.687	16.720	16.753	620
630	16.753	16.786	16.819	16.852	16.886	16.919	16.952	16.985	17.018	17.051	17.084	630
640	17.084	17.117	17.150	17.184	17.217	17.250	17.283	17.316	17.350	17.383	17.416	640
650	17.416	17.450	17.483	17.516	17.549	17.583	17.616	17.649	17.683	17.716	17.750	650
660	17.750	17.783	17.816	17.850	17.883	17.917	17.950	17.984	18.017	18.051	18.084	660
670	18.084	18.118	18.151	18.185	18.218	18.252	18.285	18.319	18.353	18.386	18.420	670
680	18.420	18.454	18.487	18.521	18.555	18.588	18.622	18.656	18.689	18.723	18.757	680
690	18.757	18.791	18.824	18.858	18.892	18.926	18.960	18.993	19.027	19.061	19.095	690
700	19.095	19.129	19.163	19.197	19.230	19.264	19.298	19.332	19.366	19.400	19.434	700
710	19.434	19.468	19.502	19.536	19.570	19.604	19.638	19.672	19.706	19.740	19.774	710
720	19.774	19.808	19.843	19.877	19.911	19.945	19.979	20.013	20.047	20.081	20.116	720
730	20.116	20.150	20.184	20.218	20.252	20.287	20.321	20.355	20.389	20.423	20.458	730
740	20.458	20.492	20.526	20.560	20.595	20.629	20.663	20.698	20.732	20.766	20.801	740
750	20.801	20.835	20.869									750
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F

* CONVERTED FROM DEGREES C(IPTS 1968).

TYPE T

NEW REFERENCE TABLES
SUPERSEDES N.B.S. CIRCULAR #561

FIELD CALIBRATION PROCEDURES

for

TEMPERATURE CONTROLLER 012003

PRELIMINARY INFORMATION

The 012003 controller has seventeen trimming adjustments in addition to its nine Operator's Controls. Twelve of these trimpots are 'factory adjustments'. These will not normally require further adjustment in the field. The five remaining adjustments should be checked periodically in the field, in order to assure that the controller remains fairly accurate. These adjustments are covered in the following procedure.

The equipment that is required in order to do these adjustments is indicated on our drawing 470270.

Those who wish to do a complete check of the controller in their metrology lab or service shop, should refer to the ALLIGNMENT, CALIBRATION & MINIMUM PERFORMANCE CHECKS, which follows this procedure.

WARNING

An electrical potential of 115 volts AC at 50-60 Hz is present on the circuit board in the area of the transformer and the terminal block marked TB1. Keep your hands and tools away from this area. Should any part of your body come into contact with this potential, you might be seriously injured, directly or indirectly, as a result of

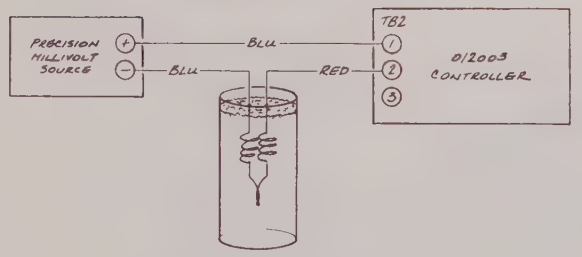
ELECTRICAL SHOCK

In the remaining areas of the circuit board low DC voltages [less than 30vdc] are less hazardous to life, however short circuiting these potentials might result in permanent damage to the controller. So be careful when useing screwdrivers and test probes.

SET UP #2

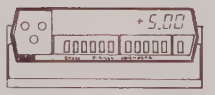
IF YOU HAVE A GOOD "PORTABLE", A HONEYWELL 2736 OR BETTER, AND IF IT IS PROPERLY MAINTAINED, THIS SET UP CAN BE AS ACCURATE AS #1. SINCE THE PORTABLE COMPENSATES AUTOMATICALLY FOR THE JUNCTION FORMED AT ITS (−) TERMINAL, THIS SET UP IS THE MOST CONVENIENT AND THE LEAST TIME CONSUMING.

SET UP #1



MELTING CRUSHED ICE, SATURATED WITH WATER. AT LEAST SIX INCHES OF THE THERMOCOUPLE SHOULD BE SUBMERGED IN THE CENTER OF THIS BATH, NOT TOUCHING THE BOTTOM OR SIDES OF THE CONTAINER.

0°C/+32°F IS DEFINED AS THE TEMPERATURE AT WHICH WATER FREEZES, ORICE MELTS. MOST THERMOCOUPLE CALIBRATION TABLES ARE REFERENCED TO THIS POINT, BECAUSE IT IS FAIRLY EASY TO REPRODUCE WITH A HIGH DEGREE OF ACCURACY.



DIGITAL VOLTMETER

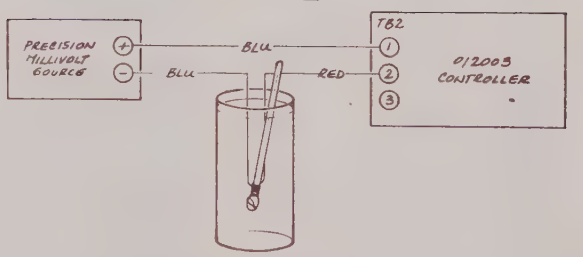
ALL OF OUR ALLIGNMENT & CALIBRATION PROCEDURES CALL FOR THE USE OF A DVM, A FLUKE MODEL 8000A OR EQUAL. NEVER USE A VTVM WITH AN ANALOG METER, OR A REGULAR VOLTMETER. THE ACCURACY OF SUCH METERS IS NOT TYPICALLY BETTER THAN 1% TO 2%, WHICH CONVERTS/POUNDS TO ERRORS AS LARGE AS ±10°F. THE ACCURACY OF THE 8000A IS ABOUT ±.1%.

REFER TO THE WRITTEN PROCEDURE FOR STEP BY STEP INSTRUCTIONS ON HOW TO CALIBRATE THE CONTROLLER.

WHEN MAKING THE ABOVE WIRING CONNECTIONS, USE ONLY COPPER IS CONSTANTAN THERMOCOUPLE WIRE:

BLUE = COPPER (+)
RED = CONSTANTAN (−)

SET UP #3



WRAP A THERMOCOUPLE AROUND A GOOD MERCURY THERMOMETER AND SUBMERGE AT LEAST SIX INCHES OF THE WIRE INTO WATER. ALLOW THE BATH TO STABILIZE AT ROOM TEMPERATURE PRIOR TO USE.

IF CAREFULLY DONE, THIS SET UP CAN APPROACH THE ACCURACY OF #1 OR #2. YOU MUST USE AN ACCURATE THERMOMETER SINCE ANY ERROR THERE WILL BE INCLUDED DIRECTLY IN YOUR CALIBRATION.

THERMOTRON CORPORATION
HOLLAND, MICHIGAN 49423

NO	CHANGES	DATE	BY	CH'K'D	NO.	CHANGES	DATE	BY	CH'K'D

TOLERANCE
SCALE
MATERIAL
FINISH
DRAWN BY FOERSTER DATE JAN 78
CHECKED BY DATE
RELEASED BY DATE

DESCRIPTION
CONTROLLER CALIBRATION SET UPS
REF: 012003

470270

1. POWER SUPPLY ADJUSTMENTS

The controller power supply includes a +15v regulated supply and a -15v regulated supply. These two supplies are used to provide referance voltages at several points in the controller circuitry, so its important that they be properly adjusted.

1.1. Connect the DVM [+] lead to R82 [orange-black-gold-gold] on the end marked [+]. Connect the DVM [-] lead to TB2, terminal 1.

1.2. The DVM indication should now be +15.00v. If not, adjust R84 as necessary to produce this indication.

1.3. Now connect the DVM [+] lead to the case of IC5.

1.4. The DVM indication should now be -15.00v. If not, adjust R86 as necessary to make it -15.00v.

2. RJC CHECK

The accuracy of the controller's temperature measurement depends upon the proper operation of its referance junction compensator circuit. So the operation of this circuit should be checked.

2.1. Connect the DVM [+] lead to the right-hand end of R5, right next to the '2' of the legend 'TB2'.

2.2. The DVM indication should alternate between about -0.4v and +13.5v at a rate of about 1½ cycles per second. If 'stuck' at either extreme, the RJC circuit is not operating properly and the controller should be removed for service.

3. TEMPERATURE ZERO & SPAN CALIBRATION

The controller measures temperature by means of a thermocouple sensor. This measurement can be very accurate when the measuring circuits are properly calibrated. In order to control accurately the measurement must, obviously, be accurate.

A few precautions:

- These controllers have the capability of driving temperature indicators. If the system has such an indicator, it must be calibrated separately later on. For the time being, ignore it.

- A thermocouple is made by connecting the ends of two dissimilar wires; in this case, copper and constantan. Where the dissimilar wires touch, a temperature sensitive junction is formed.

Differant types of materials give a differant response. Therefore, in the following procedure you must use copper and constantan thermocouple wire ONLY. Otherwise, your calibration will be wrong.

- Refer to our drawing 470270. Here we show the three possible calibration set ups. One of these, and none others, must be used. The order of preferance is indicated on the drawing. The point is, all junctions in the sensor wiring must be accounted for, since they are all temperature sensitive. When this is not done, significant errors will result, and it might even be impossible to calibrate the controller.

- If the controller is installed and wired into heating and cooling equipment, positively disable this equipment before you proceed. During this procedure you will be feeding false temperature information to the controller, and this could result in unsafe operation of any associated heating and cooling equipment.

- You will temporarily disconnect the controller's thermocouple sensor. When finished with the calibration, be sure that it is properly reconnected, else the controller will not operate properly.

3.1. Disconnect the controller's thermocouple at TB2, terminals 1 and 2. In its place, connect the extension wires from your calibration set up:

TB2-1: + [copper] BLUE insulated wire
TB2-2: – [constantan] RED insulated wire

Notice the small constantan wire which is permanently connected to TB2-2. Your constantan wire should physically touch this wire.

3.2. Connect the DVM [+] lead to TB3, terminal 9. Then connect the DVM [-] lead to TB3, terminal 7.

3.3. Now adjust your set up as follows:

Set Up 1: Set the millivolt source at exactly -3.006mv.

Set Up 2: Set the portable potentiometer at exactly -125F, or -3.006mv.

Set Up 3: Read the temperature of the water without disturbing the thermometer. Refer to the 'T' table and find the millivolt value corresponding to that temperature. Algebraically subtract this value from -3.006mv, and set the millivolt source to this corrected value.

[example on next page]

Example: 75F water = 0.947mv

thus, -3.006mv
-0.947mv
-3.953mv

3.4. The DVM should now indicate 0.000v. If not, adjust R13 as necessary to achieve this indication.

3.5. Now readjust your set up:

Set Up 1: Set the millivolt source at exactly +8.787mv.

Set Up 2: Set the portable potentiometer at exactly +375F, or +8.787mv.

Set Up 3: Read the water temperature without disturbing the thermometer. Again refer to the 'T' table and find the millivolt value corresponding to that temperature. Subtract this value from +8.787mv, and set the millivolt source to this corrected value.

Example: 75F water = 0.947mv

thus, +8.787mv
-0.947mv
+7.840mv

3.6. The DVM should now indicate +5.00v. If not, adjust R19 as necessary to achieve this indication.

3.7. Unless you have a temperature indicating device in your system, disconnect your test set up, and reconnect the controller's thermocouple sensor:

TB2-1: + [copper] BLUE insulated wire
TB2-2: – [constantan] RED insulated wire

4. TEMPERATURE INDICATOR CALIBRATION

If your system includes a temperature indicating meter, it is nost likely a Thermotron Model 013005. If it is some other type, you will have to extrapolate these instructions to that device if it has no instructions of its own.

4.1. Vary the setting of your test set up until the DVM reads 0.000v. Now adjust the mechanical zero adjustment on the front of the meter so that its pointer indicates exactly -125F.

4.2. Vary the setting of your test set up until the DVM reads +5.00v. Now adjust the electrical span adjustment on the back of the meter [R2] so that the pointer indicated exactly +375F.

5. SET POINT CALIBRATION

The set point is the controller's instruction. It tells the controller what temperature to control. The controller has no set point station of its own, but can supply power to remote set point potentiometers. This is the case when the 013005 Indicator/Set Point Assembly is used with the controller, or if a single potentiometer is used to establish the set point. If your system has some other set point source, refer to its instructions. Otherwise, proceed as follows.

5.1. Connect the DVM [+] lead to TB3, terminal 8, and its [-] lead to TB3, terminal 7.

5.2. Adjust the set point index to +375F. The DVM should now indicate +5.00v exactly. If not, adjust R22 as necessary to provide this indication.

NOTE: There is no zero adjustment for the set point on 013005 units. When the set point is moved to -125F, the DVM should read 0.00v. If not, the unit is defective. Where a single potentiometer is used as the set point adjustment, its knob should be mechanically zeroed prior to doing step 5.2.

ALLIGNMENT, CALIBRATION & MINIMUM PERFORMANCE CHECKS

for

TEMPERATURE CONTROLLER 012003

PRELIMINARY INFORMATION

The 012003 Controller is a precision device. As such, it includes several adjustments which serve to set circuit values to within closer tolerances than can be achieved through the selection of standard fixed componet values.

These adjustments are all rechecked, and reset if necessary, at the factory following burn in of the controller. Most of them should not require any attention in the field until, perhaps, after several years of operation, or unless they are inadvertantly disturbed, or if the device has been subjected to rough handling or severe vibration.

The FIELD CALIBRATION PROCEDURE covers those adjustments which should be checked as a normal part of field maintenance and service activities. For field activities that procedure should be used.

This procedure is intended for factory production and test, factory service, and bench level service at field repair stations. Units which can successfully meet these minimum performance requirements can be considered to be fully serviceable, and able to perform their designed functions within the limits of their specification.

EQUIPMENT REQUIRED

1. Digital Voltmeter, Fluke Model 8000A, or equal
   [Do not attempt to use a VOM or VTVM since the accuracy of analog type meters is not satisfactory for this procedure.]
2. Oscilloscope, Tektronix 212, or equal.
3. Precision Voltage Source, Thermotron 434004, or equal.
4. Portable Potentiometer, Honeywell Model 2736, or equal.
5. Variac, Superior Electric 116B, or equal.
6. Resistor, 330 Ohms, ¼w, 5%.
7. Resistor, 1.5K, ¼w, 5%.
8. Stop Watch, Galco Model 955, or equal.

GENERAL PROCEDURE

This procedure works through the controller circuitry in the following order:

1. D.C. POWER SUPPLY & REGULATOR CIRCUITS
2. REFERANCE JUNCTION COMPENSATOR CKT
3. AMPLIFIER & SCALEING CIRCUITS
4. SET POINT BUFFER & DEVIATION AMP CKTS
5. PROPORTIONING WAVE GENERATOR CKTS
6. HEAT PROPORTIONING CIRCUITRY
7. COOL PROPORTIONING CIRCUITRY
8. MACHINERY CONTROL CIRCUITS

In general, this order should be adhered to since the results that are to be achieved in a given section may be contingent upon having properly completed some procedure in a previous section. For instance, everything in sections 2 thru 8 assumes that section 1 has been properly completed. If this is not the case, any subsequent power supply adjustment might introduce significant errors in the adjustments previously accomplished in other circuitry.

Unless otherwise specified, the Operator's Controls are to be set as follows during this procedure:

R43	HEAT P ZONE	0%
R61	HEAT RESET	0%
R71	HIGH LIMIT	100%
R49	COOL P ZONE	0%
R52	COOL RESET	0%
R69	LOW LIMIT	0%
R39	PULSE RATE	120PPM
R81	MACH TIME OUT	5Sec
R26	DEV SPAN	±5%

After completing each segment of the procedure, the set up for that segment should be torn down unless the next segment calls for it to be retained.

Line power should be applied to terminals L, N and E of TB1 [Line, Neutral and Earth] from the variac, which should be set at 115vac unless otherwise specified in the procedure.

Terminals 9 and 10 of TB3 are normally shorted togather with a permanent jumper wire. Several parts of this procedure call for the temporary removal of this jumper. Always reconnect it when finished with those parts of the procedure, and be sure that it is properly connected before releasing the controller for stock, shipment or use.

1. D.C. POWER SUPPLY & REGULATOR CIRCUITS

The power supply system produces four dc potentials; +30v unregulated, -30v unregulated, +15v regulated and -15v regulated. Checks include:

1.1. Unregulated voltage levels
1.2. Regulated voltage levels
1.3. Line regulation
1.4. Load regulation
1.5. Nominal load current
1.6. Current limit operation
1.7. Oscillation, noise and transient response

1.1. Unregulated Voltage Levels

Connect the DVM between IC28-3 and ground. Set the line voltage [variac] at 115vac. The DVM should indicate +27v $\pm$4v. When the RJC circuit switches ON, this level will be reduced to +23v $\pm$2v. This happens 2 or 3 times per second.

Connect the DVM between IC29-5 and ground. With the line voltage at 115vac, the DVM should indicate -29v $\pm$2v. The operation of the RJC circuit will decrease this level only slightly, to about -26v.

1.2. Regulated Voltage Levels

Connect the DVM between IC28-8 and ground. Set the line voltage at 115vac. The DVM should indicate +15.00v. If not, adjust R84 until this indication is achieved.

Connect the DVM between IC29-8 and ground. With the line voltage at 115vac, the DVM indication should be -15.00v. If not, adjust R86 to produce this indication.

1.3. Line Regulation

Connect the DVM between IC28-8 and ground. The specified line voltage range for the controller is 90vac to 130vac. As the line voltage is varied between these limits, the DVM indication must remain within the limits of +14.98v to +15.02 v.

Connect the DVM between IC29-8 and ground. Repeat the above procedure for the -15v supply. The DVM indication must remain within the limits of -14.98v to -15.02v.

1.4. Load Regulation, Load Current & Current Limit

Connect the DVM across R82. The DVM indication will be about 180mV ±20mV. This represents a nominal load current of about 60mA. This level pulses with the operation of various circuits in the controller, but will remain within the above limits.

Connect the DVM between IC28-8 and ground. Connect a 330 Ohm resistor between the leads of the DVM. This increases the load current to about 100mA. When this is done, the DVM indication should remain within the limits of +14.98v to +15.02v.

Disconnect the resistor, and connect the DVM across R82. Now short IC28-8 to ground. The DVM indication should now rise to between 345mv and 405mv. This represents a current limit of between 115mA and 135mA.

Leave the short in place, and connect the DVM between IC28-8 and ground. The DVM indication will be about +.01v. When the short is removed, the indication will immediately recover to within the limits of +14.98v and +15.02v.

Connect the DVM across R88. The DVM indication will be about 275mv ±20mv. This represents a nominal load current of about 54mA. This level pulses with the operation of various controller circuits, but will remain within the above limits.

Connect the DVM between IC29-8 and ground. Connect a 330 Ohm resistor between the leads of the DVM. This increases the load current to about 100mA. When this is done, the DVM indication should remain within the limits of -14.98v and -15.02v.

Disconnect the resistor, and connect the DVM across R88. Now short IC29-8 to ground. The DVM indication should rise to between 590mv and 690mv. This represents a load current limit of between 115mA and 135mA.

Leave the short in place, and connect the DVM between IC29-8 and ground. The DVM indication will be about -.01v. When the short is removed, the indication will immediately recover to within the limits of -14.98v and -15.02v.

1.5. Oscillation, Noise & Transient Response

Connect the oscilloscope between IC28-8 and ground. The combined amplitude of any oscillation, noise and transient spikes should not exceed 20mv peak to peak.

Connect the oscilloscope between IC29-8 and ground. The same limits apply to this point; the composit signal not exceeding 20mv peak to peak.

2. REFERANCE JUNCTION COMPENSATOR CIRCUIT

The RJC circuit is a precision temperature control system designed to hold the temperature of the sensor circuit's second junction, or 'referance junction' very stable at about +160F. Checks include:

2.1. Referance temperature
2.2. Warm up time
2.3. Pulse rate
2.4. Referance temperature stability

2.1. Referance Temperature

Connect the Honeywell Potentiometer, Model 2736 or equal, between TB2-2 [-] and TB2-3 [+]. Disconnect any connection at TB2-1.

If necessary, allow a warm up period of sixty seconds prior to measuring this temperature with the potentiometer. The measured RJC temperature must be within the limits of +150F to +170F.

2.2. Warm Up Time

Connect the Potentiometer between TB2-2 [-] and TB2-1 [+], and set its EMF output at exactly +157.5F.

Connect the Precision Voltage Source, Thermotron 434004 or equal, between TB3-7 [-] and TB3-8 [+]. Use the E1 output and set it at 2.500v.

Useing the E2 output of the voltage source, calibrate the oscilloscope for a vertical gain of 100mv/cm. Then connect the oscilloscope across R27.

Connect a Thermotron 123005 deviation meter, else a jumper wire, between TB3-5 [-] and TB3-4 [+]. Set R26 fully cw.

Apply power to the controller and allow a warm up period of 120 seconds. Then set voltage source E1 as necessary to zero the oscilloscope. Turn the controller OFF and allow five minutes for the RJC element to return to ambient temperature.

Simultaniously turn the controller ON and start the stop watch, then observe the oscilloscope. Within 180 seconds the trace must come to within ±100mv of zero. This is about equal to ±.33F.

2.3. Pulse Rate

Note that the scope trace pulses at a rate of about one pulse per second. Useing the stop watch, measure the time required for ten pulses. The measured time must not exceed ten seconds.

2.4. Referance Temperature Stability

Retaining the above set up, trim the setting of voltage source E1 as necessary to zero the oscilloscope. Then observe the trace during a period of 120 seconds. During this time, no part of the trace may vary outside of the limits of ±100mv.

IMPORTANT NOTE

When the controller is equipped with RJC assy p/n 169001, this part must be shielded from drafts during all of the above tests. Preferably, the tests should be conducted with the cover properly installed on the controller. If this is not possible, the RJC assy itself may be covered useing a small plastic aerosol cap, or some other suitable device. When this is done, the cover must not physically contact the RJC element.

If this precaution is not observed, errors on the order of ±.5F will typically occur, and errors as large as ±2.5F might occasionally be observed.

These same precautions apply to the Portable Potentiometer, with respect to its terminals. Errors of the same magnitude can be produced by this source, since the temperature of the [-] terminal can change faster than the compensator in the instrument can respond. Keep this instrument out of drafts, and hands away from its terminals, while measurements are being taken. If possible, close its cover during these measurements.

3. AMPLIFIER & SCALEING CIRCUITS

The algebraic sum of the mj and rj emf's is fed to the amplifier and scaleing circuits. These circuits convert this low level emf signal to a voltage analog of temperature on a 'percent of span' basis: 0%/100% = 0v/+5v [≙-125F/+375F]. Checks include:

3.1. Zero point
3.2. Span point
3.3. Noise
3.4. Open sensor protection

3.1. Zero Point

Connect the Portable Potentiometer between TB2-2 [-] and TB2-1 [+].

Connect the DVM between TB3-10 and TB3-7.

Set the Potentiometer's EMF output at exactly -125F. At this time the DVM indication should be 0.00v. If not, adjust R13 as necessary to achieve this indication.

3.2. Span Point

Retaining the above set up, set the Potentiometer's output at exactly +375F. The DVM indication should now rise to exactly 5.00v. If not, adjust R19 as necessary to produce this reading.

If desired, linearity may now be checked as follows:

EMF Set	DVM Indication
-125F	0.00v
0	0.99
+100	1.92
+200	2.96
+300	4.09
+375	5.00

3.3. Noise

Connect the oscilloscope in parallel with the DVM leads. There should be no sign of oscillation or referance junction pulseing when the scope is set for a vertical sensitivity of 50mv/cm [AC input mode]. The level of white noise, or 'grass', should not exceed 20mv peak to peak, as seen with this set up [includes meter noise, scope noise, leadwire pick up, etc.].

3.4. Open Sensor Protection

IC2 is a non-inverting amplifier and will saturate if its input is allowed to float; this mechanism provides inherant TCBO protection for the controller via the failsafe limit circuits.

Retaining the above set up, disconnect one input lead at the Potentiometer. This should cause the DVM indication to rise to about +13.70v. In some cases the amplifier might

first swing to a negative value, then switch abruptly into positive saturation. This is an acceptable indication since the failsafe circuits will interpret anything less than zero, and anything more than +5v, as a fault condition.

Set the EMF output of the Potentiometer at exactly 157.5F and reconnect the input leadwire. The DVM indication should immediately return to +2.50v.

4. SET POINT BUFFER & DEVIATION AMPLIFIER CIRCUITS

The set point buffer accepts a 0v/+5v set point signal from remote sources. It offers a high dc input impedance to prevent loading of such sources, and reproduces the set point signal at its low impedance output.

The deviation amplifier compares the set point signal with the temperature signal, and produces an output current which is proportional to the differance, if any. This current is used to operate a deviation meter.

Checks include:

4.1. Set Point Zero
4.2. Set Point Span
4.3. Set Point Noise
4.4. Deviation Zero
4.5. Deviation Span

4.1. Set Point Zero

Connect a jumper wire between TB3-7 and TB3-8.

Connect the DVM between IC6-6 and ground. At this time the DVM indication must be 0.00v ±.005v.

4.2. Set Point Span

Connect a jumper wire between TB3-8 and TB3-11.

Connect an 8.119K resistor [7.5K + 619 Ohms] between TB3-7 and TB3-8.

Connect the DVM between IC6-6 and ground. The DVM should now indicate 5.12v. If not, adjust R22 as necessary to produce this indication.

4.3. Set Point Noise

Retaining the above set up, connect the oscilloscope in parallel with the DVM leads. There should be no sign of oscillation. The level of white noise should not exceed 20mv peak to peak, as seen with this set up [includes meter noise, scope noise, leadwire pick up, etc.].

4.4. Deviation Zero

Temporarily remove the jumper between TB3-9 and TB3-10. Connect a jumper between TB3-9 and TB3-7, and between TB3-8 and TB3-7.

Connect the DVM across R27, and turn R26 fully cw. The DVM indication should be within the range of ±30mv. This is about equal to ±.1F.

4.5. Deviation Span

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Set E1 at 5 .000v.

Connect voltage source E2 between TB3-7 [-] and TB3-9 [+]. Set E2 at 5.000v.

Connect the DVM across R27, and connect a jumper wire between TB3-4 and TB3-5.

Mechanically zero the knob of R26 at the ccw dot; set the knob at ±5%.

Now set E2 at 4.750v. This should produce a DVM indication of between -7.125v and -7.875v.

Next, set E2 at 5.250v. The DVM indication must now be within the range of +7.125v to +7.875v. This is about equal to ±1.25F.

NOTE

An out of tolerance reading here means that R26 is not within tolerance, and should be changed. The correct value may be calculated:

$$R26' = \frac{R26''\left(\frac{Em}{.25}\right)}{30}$$

where: R26' = correct value
R26''= original (measured) value
Em = voltage measured above

5. PROPORTIONING WAVE GENERATOR CIRCUITRY

The proportioning wave generator circuits generate two triangle waves. These waves are added to, and subtracted from, the set point signal in the cooling and heating sections of the controller, in order to develop its proportioning action. Checks include:

5.1. +7.5v referance
5.2. Low pulse rate calibration
5.3. High pulse rate calibration
5.4. Heating wave calibration
5.5. Cooling wave calibration

5.1. +7.5v Referance

Connect the DVM between IC8-3 and ground. Set R39 fully ccw.

The DVM indication will alternate between some positive level and zero. Adjust R31 as necessary to set the positive level at exactly +7.50v.

On the low part of the cycle, the DVM should indicate 0v ±2.5mv.

5.2. Low Pulse Rate Calibration

Connect the DVM between IC10-6 and ground. Turn R39 fully ccw, and mechanically zero its knob at the dot.

The DVM indication will alternate between negative and positive levels. Adjust R35 to set the positive level at 225.0mv.

Connect the oscilloscope to IC8-6. Useing the stop watch measure the exact time for twelve complete cycles, as displayed on the scope. This time should be exactly 120 seconds. If not, calculate a corrected setting for R35 as shown below, and readjust R35 accordingly.

$$E_2 = E_1 \left(\frac{T}{120} \right)$$

where: E_2 = correct setting in volts
E_1 = initial setting in volts [.225v]
T = measured time for 12 cycles

Useing the stop watch and the scope, verify that the time for six cycles is now exactly sixty seconds.

5.3. High Pulse Rate Calibration

Retaining the above set up, set R39 at 120PPM. Useing the stop watch and the scope, measure the exact time for 120 complete cycles. This time should be exactly sixty seconds. If not, proceed as follows:

Set R39 at 6PPM. Connect the DVM between the ccw (brn) end of R39 and ground. The DVM indication will alternate between negative and positive levels. Record the positive level and label it 'E_1'.

Now compute a corrected value for this voltage, then adjust R38 to provide this indication on the positive half cycle:

$$E_2 = E_1 \left(\frac{T}{60}\right)$$

where: E_2 = correct setting in volts
E_1 = measured initial setting in volts
T = measured time for 120 cycles

Return R39 to the 120PPM setting. Useing the stop watch and the scope, verify that the time for 60 cycles is now exactly 30 seconds.

5.4. Heating Wave Calibration

Connect the voltage source E2 between IC8-3 [+] and ground [-], and set E2 at 7.500v.

Connect the DVM in parallel with E2, and verify that the voltage at IC8-3 is now maintained at +7.5v, with no variation.

Now connect the DVM between IC20-3 and ground. Turn R43 fully ccw, and mechanically zero its knob at the dot, then set R43 at -5%.

At this time, the DVM should indicate exactly -250mv. If not, adjust R42 as necessary to produce this indication.

5.5. Cooling Wave Calibration

Retaining the above set up, connect the DVM between IC16-3 and ground.

Turn R49 fully ccw, and mechanically zero its knob at the dot, then set R49 at +5%.

At this time, the DVM should indicate exactly +250mv. If not, adjust R48 as necessary to produce this indication.

6. HEAT PROPORTIONING CIRCUITRY

The heat proportioning circuitry algebraically adds the set point signal, the proportioning wave and the reset signal. This sum is then compared with the temperature signal, and the heating output is energised whenever the temperature signal is less than the instantanious value of the composit set point signal, but not greater than a preset failsafe limit. Checks include:

6.1. Heat Set Point Zero
6.2. Heat Set Point Span
6.3. Heat Reset Accuracy
6.4. Heat Failsafe Calibration
6.5. Heat Output Signal & Proportioning

6.1. Heat Set Point Zero

Connect the DVM between IC19-6 and ground. Connect a jumper wire between TB3-7 and TB3-8.

Set both R43 and R61 fully ccw, then mechanically zero R61 at dot. Now set R61 at 0%.

The DVM should now indicate 0.00v. If not, adjust R60 as necessary to produce this indication.

6.2. Heat Set Point Span

Retain the above set up; DO NOT DISTURB the settings of R43 and R61 [0%].

Remove the jumper from TB3, and in its place connect the precision voltage source E1; TB3-7 [-] and TB3-8 [+]. Set E1 at 5.000v.

The DVM should now indicate +5.00v. If not, adjust R67 as necessary to provide this indication.

6.3. Heat Reset Accuracy

Retaining the above set up, set voltage source E2 at 4.950v, then lift the DVM lead from ground and connect it to the positive terminal of E2.

Set R61 at -1%. The DVM indication should now be within the range of from -10mv to +10mv.

Now set R61 at +5%, and set E2 at 5.250v. The DVM indication should now be within the range of from -25mv to +25mv. This is about equal to an accuracy of ±2.5F at a reset value of about +25F.

6.4. Heat Failsafe Calibration

Connect the DVM between IC23-3 and ground. Turn R71 fully ccw, and mechanically zero its knob at the dot.

Now turn the knob to 100%. The DVM indication should now be 5.00v. If not, adjust R70 to produce this indication.

6.5. Heat Output Signal & Proportioning Action

Connect a 1.5K resistor between TB3-3 and TB3-6. Connect both the DVM and the oscilloscope across this resistor.

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Connect voltage source E2 between TB3-7 [-] and TB3-9 [+], temporarily removeing the jumper wire found between TB3-9 and TB3-10. Set E1 at 2.500v and also set E2 at 2.500v.

Now set R43 at -5% and R61 at 0%. Observe the scope, and trim the setting of R61 slightly to find the point at which the controller just stops pulseing [pulse just discernable in the noise]. At this point the control knob of R61 should still be at 0%. To facilitate scope observations, set R39 at 120PPM.

Set R71 at 75%. The DVM indication must now be within the range of from 0.00v to +0.50v. Proceed as follows:

E2 Setting	Scope Observation
2.490v	ON Time = 4%
2.450v	= 20%
2.400v	= 40%
2.350v	= 60%
2.300v	= 80%
2.260v	= 96%
2.250v	=100%

At this time the DVM indication must be within the range of from 4.00v to 6.00v.

Set E1 at 5.000v, and E2 at 3.700v. The DVM indication must now be 4.00v to 6.00v.

Set E2 at 3.800v. The DVM indication must now be within ±10mv of zero. This verifies the operation of the failsafe limit circuit.

Set R71 at 100%.

7. COOL PROPORTIONING CIRCUITRY

The cool proportioning circuitry algebraically adds the set point signal, the proportioning wave and the reset signal. This sum is then compared with the temperature signal, and the cooling output is energised whenever the temperature signal is greater than the instantanious value of the composit set point signal, and within the preset failsafe limits. Checks include:

7.1. Cool Set Point Zero
7.2. Cool Set Point Span
7.3. Cool Reset Accuracy
7.4. Cool Failsafe Calibration
7.5. Cool Output Signal & Proportioning

7.1. Cool Set Point Zero

Connect the DVM between IC15-6 and ground. Connect a jumper wire between TB3-7 and TB3-8.

Set both R49 and R52 fully ccw, then mechanically zero R52 at dot. Now set R52 at 0%.

The DVM should now indicate 0.00v. If not, adjust R51 to produce this indication.

7.2. Cool Set Point Span

Retain the above set up; DO NOT DISTURB the settings of R49 and R52 [0%].

Remove the jumper from TB3, and in its place connect the precision voltage source E1; TB3-7 [-] and TB3-8 [+]. Set E1 at 5.000v.

The DVM should now indicate +5.00v. If not, adjust R58 as necessary to provide this indication.

7.3. Cool Reset Accuracy

Retaining the above set up, set voltage source E2 at 5.050v, then lift the DVM lead from ground and connect it to the positive terminal of E2.

Set R52 at +1%. The DVM indication should now be within the range of from -10mv to +10mv.

Now set R52 at -5%, and set E2 at 4.750v. The DVM indication should now be within the range of from -25mv to +25mv. This is about equal to an accuracy of ±2.5F at a reset value of about -25F.

7.4. Cool Failsafe Calibration

Connect the DVM between IC22-2 and ground. Turn R69 fully ccw, and mechanically zero its knob at the dot.

Now turn the knob to 100%. The DVM indication should now be 5.00v. If not, adjust R69 to produce this indication.

7.5. Cool Output Signal & Proportioning Action

Connect a 1.5K resistor between TB3-2 and TB3-6. Connect both the DVM and the oscilloscope across this resistor.

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Connect voltage source E2 between TB3-7 [-] and TB3-9 [+], temporarily removeing the jumper wire found between TB3-9 and TB3-10. Set E1 at 2.500v and also set E2 at 2.500v.

Now set R49 at +5% and R52 at 0%. To facilitate scope observations, set R39 at 120PPM. Observe the scope, and trim the setting of R52 slightly to find the point at which the controller just stops pulseing [pulse just discernable in the noise]. At this point the control knob of R52 should still be at 0%.

Set R69 at 75%. The DVM indication must now be within the range of from 0.00v to +.50v. Proceed as follows:

E2 Setting	Scope Observation
2.510v	ON Time = 4%
2.550v	= 20%
2.600v	= 40%
2.650v	= 60%
2.700v	= 80%
2.740v	= 96%
2.750v	=100%

At this time the DVM indication must be within the range of from 4.00v to 6.00v.

Set E1 at 3.000v, and E2 at 3.700v. The DVM indication must now be within ±10mv of zero.

Set E2 at 3.800v. The DVM indication must now be within the range of from 4.00v to 6.00v. This verifies the operation of the cool failsafe limit circuit.

8. MACHINERY CONTROL CIRCUITS

The machinery control circuits operate in conjunction with the cooling output to control the operation of mechanical refrigeration systems [compressors]. So long as the cooling output is active, or pulseing, these circuits hold the refrigeration system ON. This is accomplished by delaying the turn off time of the system with respect to the turn off time of the cooling output. The delay is adjustable over the range of 5 seconds to 120 seconds in order to accomodate the range of pulse rates and system operating characteristics. Checks include:

8.1. 120 Second Delay Calibration
8.2. Machinery Control Signal Output

8.1. 120 Second Delay Calibration

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Connect voltage source E2 between TB3-7 and TB3-9, observing the same polarity. Temporarily remove the jumper found between TB3-9 and TB3-10. Set E1 at 2.400v and set E2 at 2.500v.

Set the Operator's Controls as follows:

R43	HEAT P ZONE	0%
R61	HEAT RESET	0%
R71	HIGH LIMIT	100%
R49	COOL P ZONE	0%
R52	COOL RESET	0%
R69	LOW LIMIT	0%
R39	PULSE RATE	120PPM
R26	DEV SPAN	±5%

Turn R81 fully ccw and mechanically zero its control knob at the dot, then set this knob at 120 Seconds.

Connect a 1.5K resistor between TB3-1 and TB3-6. Then connect the oscilloscope across this resistor. The scope should indicate a positive level of about four volts.

Simultaniously, set E2 to a value of less than 2.300v and start timing with the stop watch. Now observe the scope presentation. Stop the watch when the trace falls. The trace should fall to zero in exactly 120 seconds. If not, proceed as follows.

Connect the DVM across R76. Record this voltage, which should be about 90mv, and label it 'E_1'. Now compute a corrected voltage as follows, and adjust R75 to produce this indication on the DVM.

$$E_2 = E_1 \left(\frac{T}{120}\right)$$

where: E_2 = correct setting in volts
E_1 = measured initial setting in volts
T = measured time delay

Now disconnect the DVM, and return the setting of E2 to 2.500v. Then repeat the above timing procedure to verify that the delay time is now exactly 120 seconds.

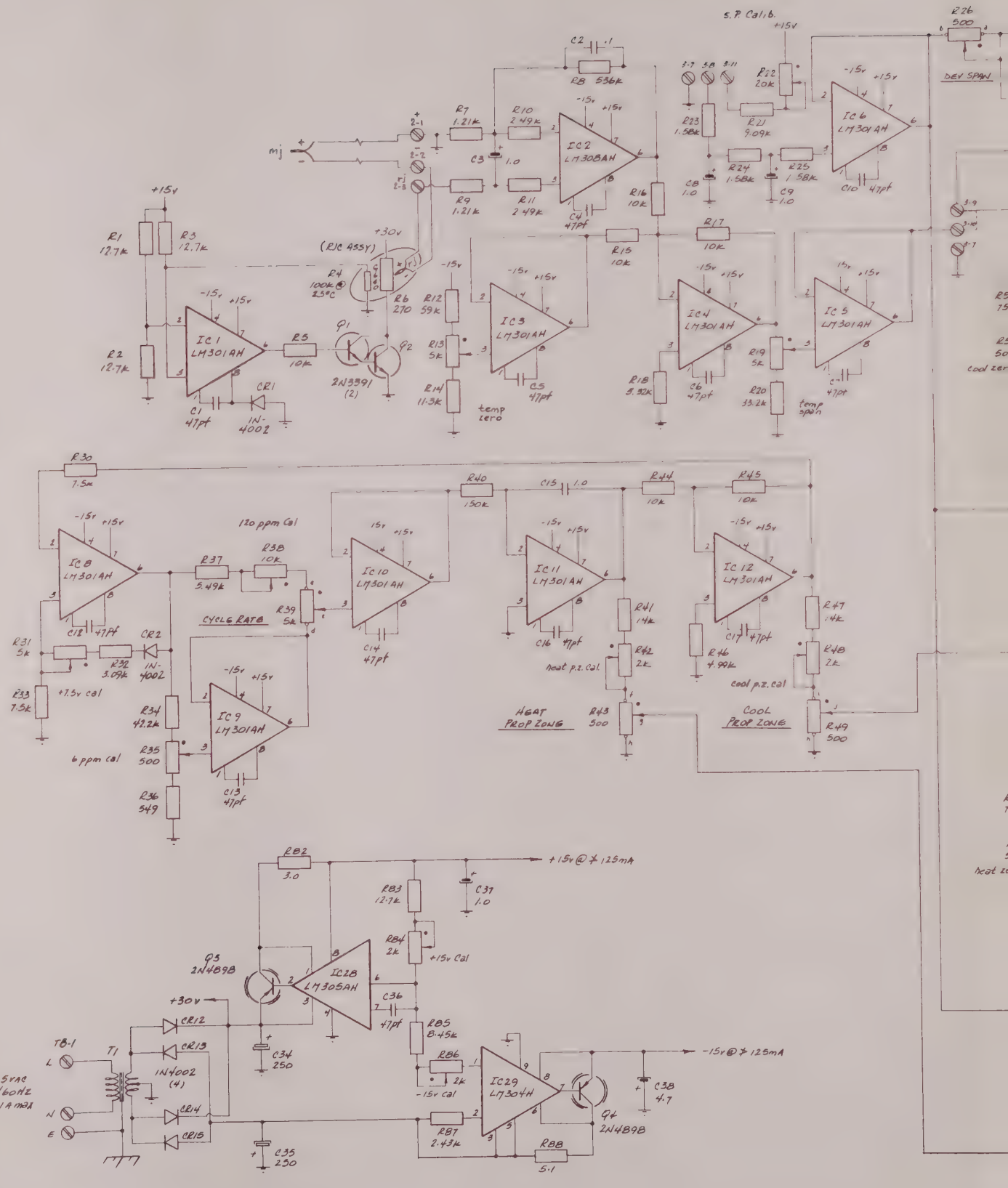
The minimum delay time can not be calibrated, and typically should be within 2.5 seconds to 5.0 seconds, depending upon finite componet values. This error will be stretched over the delay range, diminishing to zero at a setting of 120 Seconds.

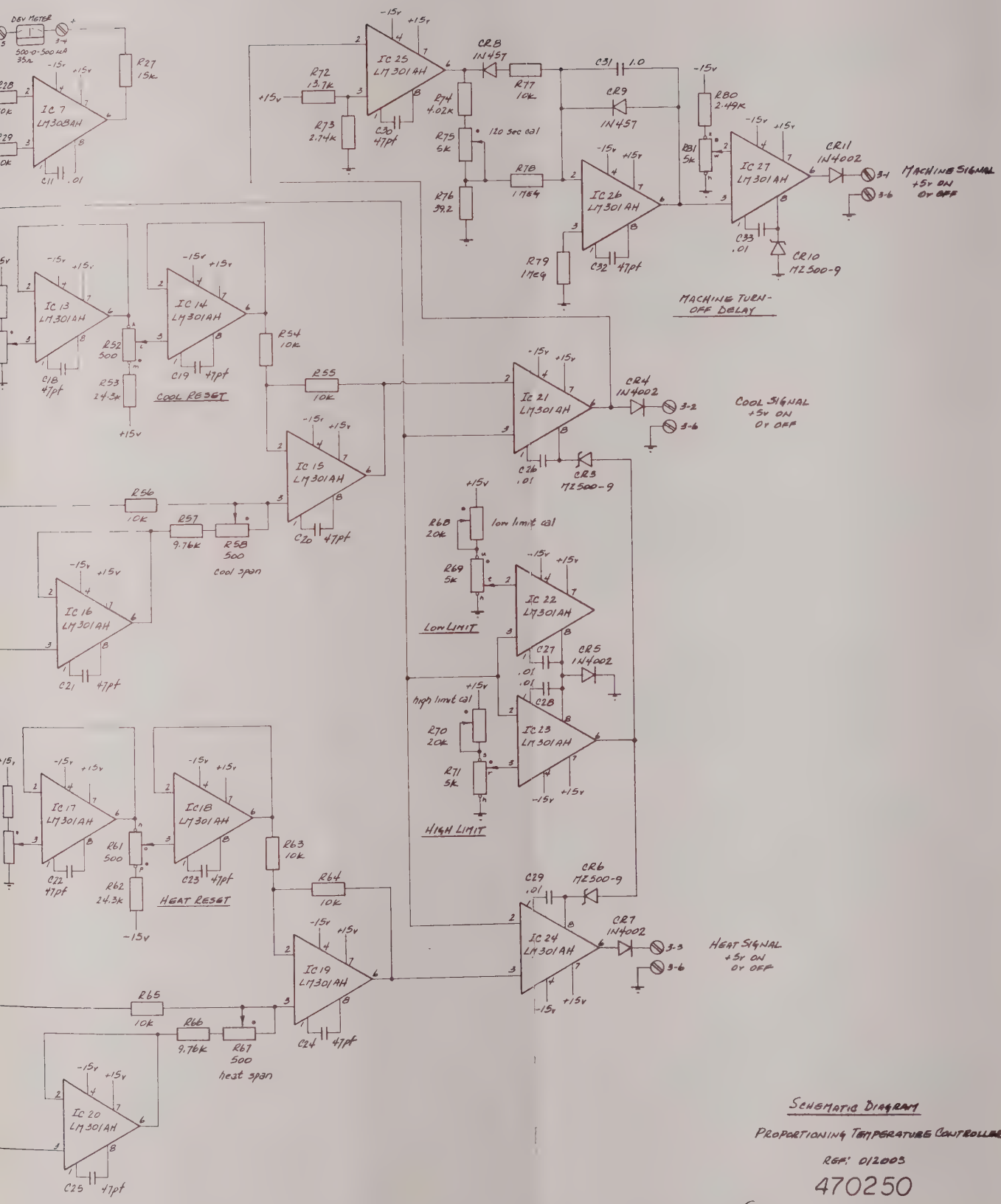
8.2. Machinery Control Signal Output

Retaining the above set up, connect the DVM between TB3-1 and ground, or across the 1.5K resistor.

Set R81 at 5 Seconds, and voltage source E2 at 2.500v. The DVM indication should now be within the range of 4.00v to 5.50v.

Next, set E2 at 2.300v. Within five seconds the DVM indication should fall to within ±10mv of zero.


S.P. Calib.
+15v
R26 500
DEV SPAN
C2 .1
R8 536k
R7 1.21k
R10 2.49k
IC2 LM308AH
C3 1.0
R9 1.21k
R11 2.49k
C4 47pf
R16 10k
R17 10k
R15 10k
mj
2-1
2-2
2-3
rj
R22 20k
R23 1.58k
R21 9.09k
R24 1.58k
R25 1.58k
C8 1.0
C9 1.0
IC6 LM301AH
C10 47pf
3-9
3-10
3-7
R1 12.7k
R3 12.7k
R2 12.7k
+30v
(RJC ASSY)
R4 100k @ 25°C
R6 270
IC1 LM301AH
R5 10k
Q1
Q2
2N3391 (2)
C1 47pf
CR1 IN-4002
R12 59k
R13 5k
R14 11.3k
temp zero
IC3 LM301AH
C5 47pf
IC4 LM301AH
C6 47pf
R18 9.32k
R19 5k
R20 33.2k
temp span
IC5 LM301AH
C7 47pf
cool zero
R30 7.5k
IC8 LM301AH
120 ppm Cal
R37 5.49k
R38 10k
R39 5k
CYCLE RATE
C18 47pf
CR2 IN-4002
R31 5k
R32 3.09k
R33 7.5k
+7.5v cal
R34 42.2k
R35 500
R36 549
6 ppm cal
IC9 LM301AH
C13 47pf
IC10 LM301AH
C14 47pf
R40 150k
C15 1.0
R44 10k
R45 10k
IC11 LM301AH
C16 47pf
IC12 LM301AH
C17 47pf
R41 1k
R42 2k
heat p.z. cal
R43 500
HEAT PROP ZONE
R46 4.99k
R47 1k
R48 2k
cool p.z. cal
R49 500
COOL PROP ZONE
RB2 3.0
+15v @ 125mA
RB3 12.7k
C37 1.0
RB4 2k
+15v Cal
Q3 2N4898
IC2B LM305AH
C36 47pf
+30v
CR12
CR13
CR14
CR15
IN4002 (4)
RB5 8.45k
RB6 2k
-15v cal
IC29 LM304H
-15v @ 125mA
C38 4.7
Q4 2N4898
RB7 2.43k
RB8 5.1
C34 250
C35 250
TB-1
T1
115vac 50/60Hz 0.1A max
L
N
E



SCHEMATIC DIAGRAM

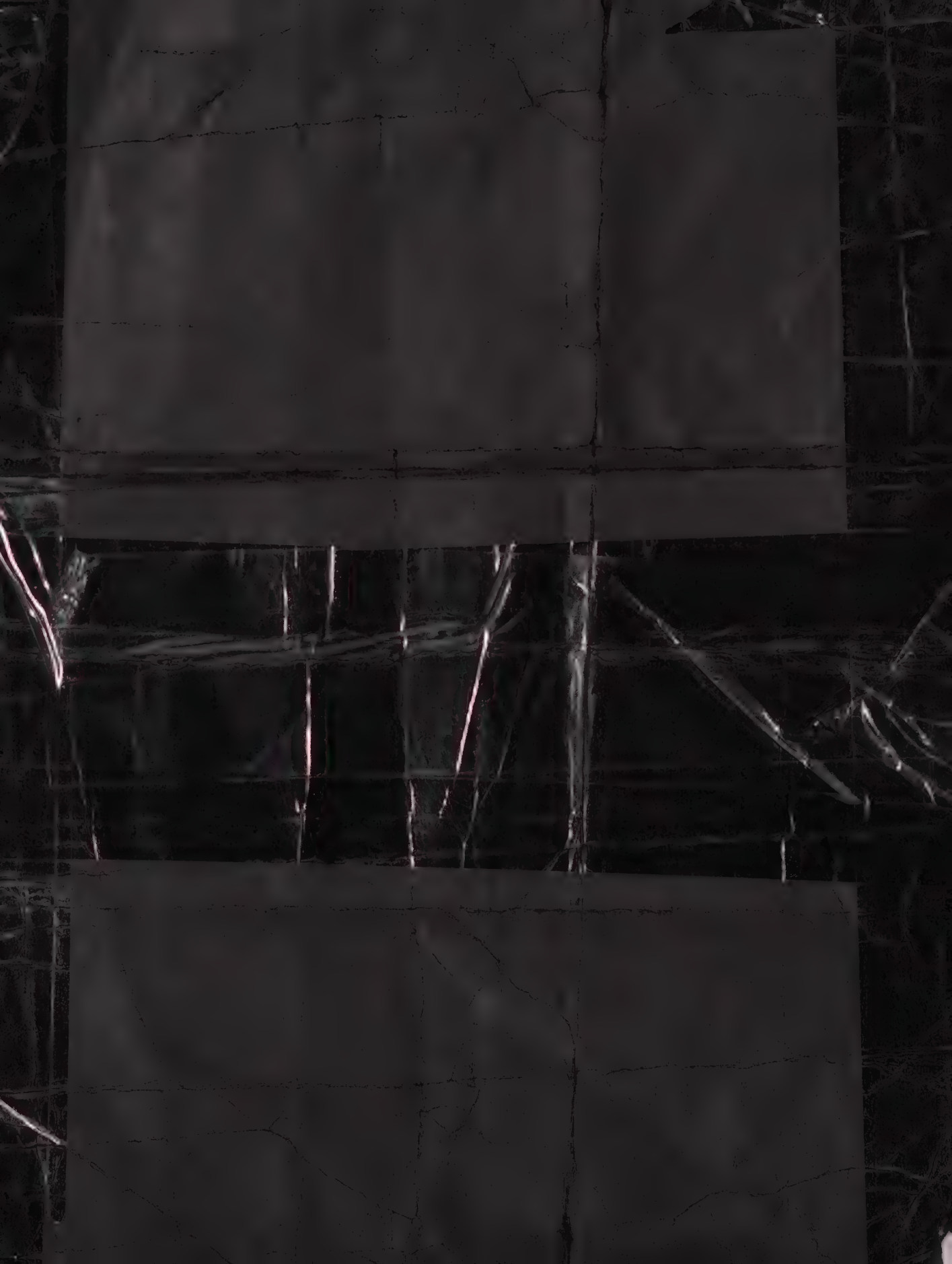
PROPORTIONING TEMPERATURE CONTROLLER

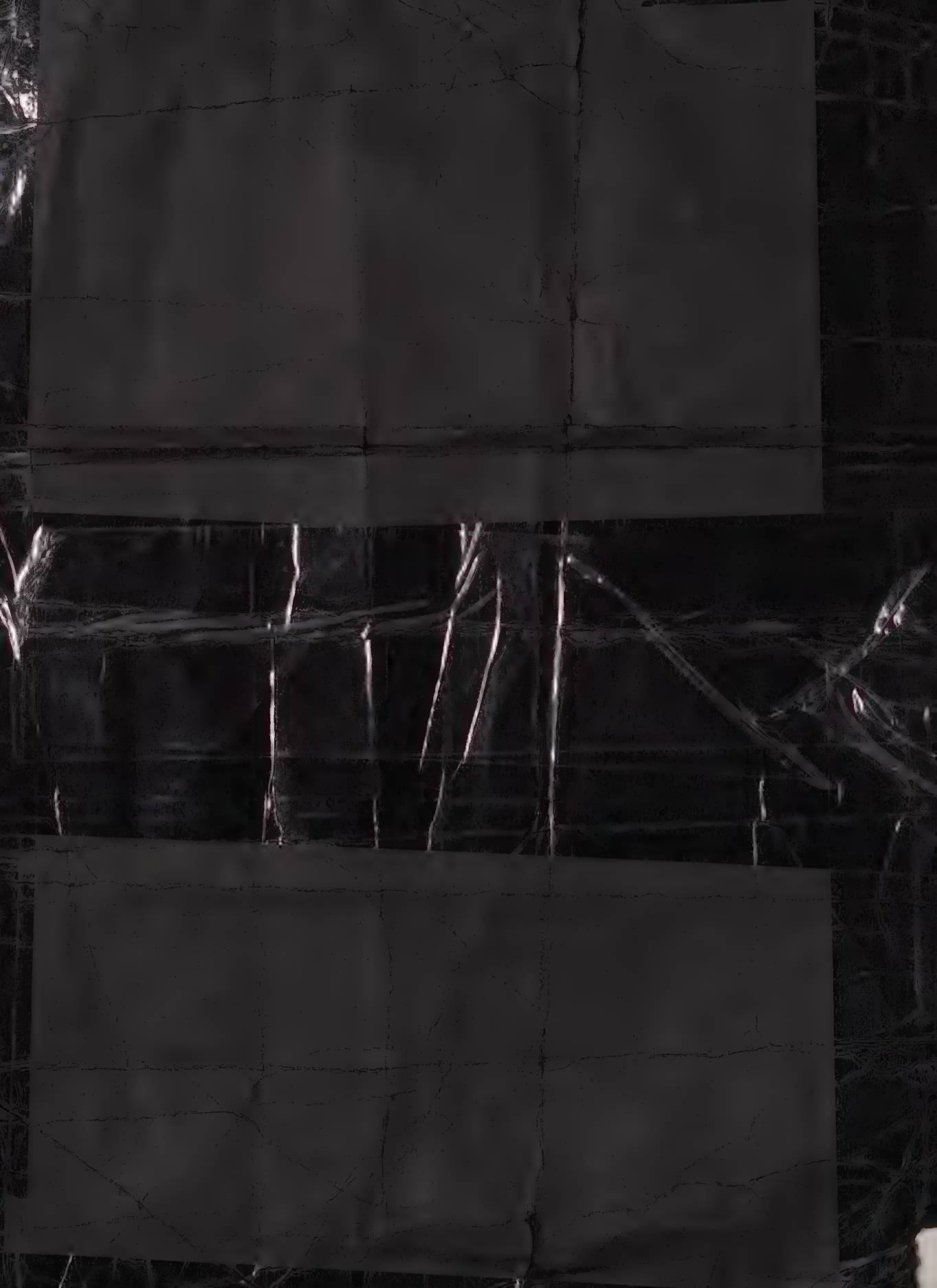
REF: 012003

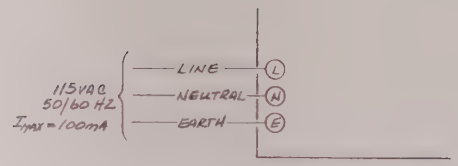
470250

CHARLIER
15 FEB 73

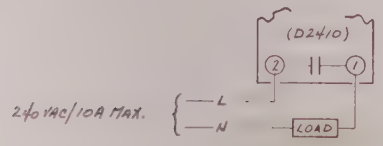
THERMOTRON CORPORATION HOLLAND, MICHIGAN USA



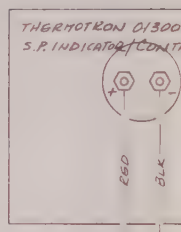


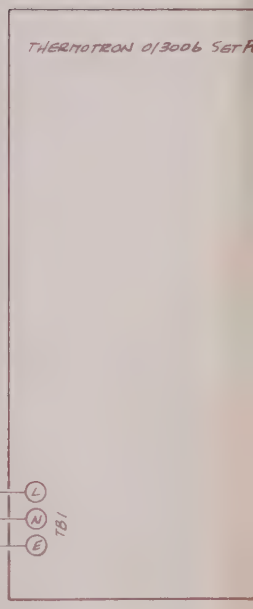


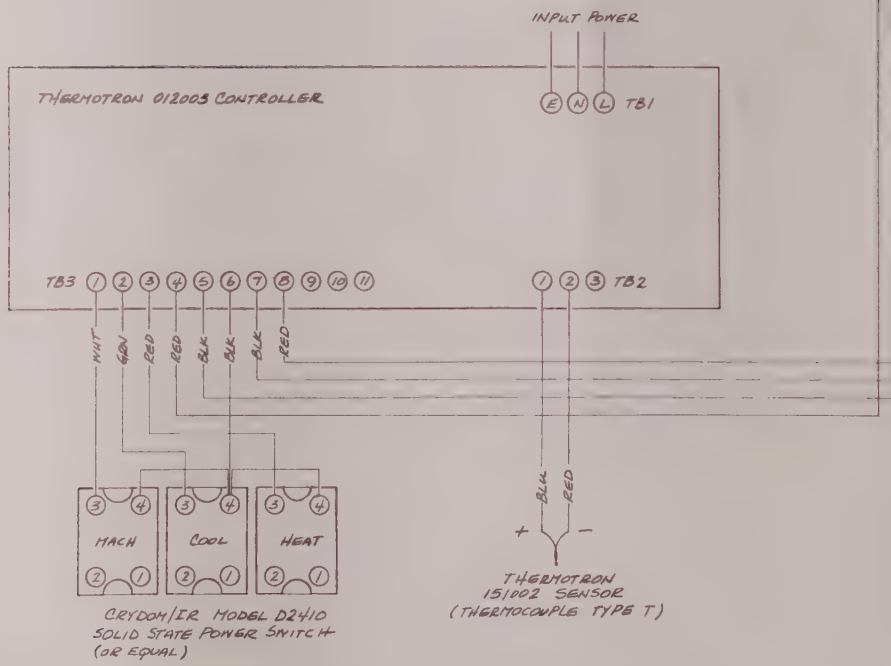
TYPICAL INPUT POWER CONNECTIONS



TYPICAL OUTPUT CONNECTIONS
(N.O. CIRCUIT)

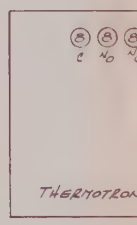






CRYDOM/IR MODEL D2410
SOLID STATE POWER SWITCH
(OR EQUAL)

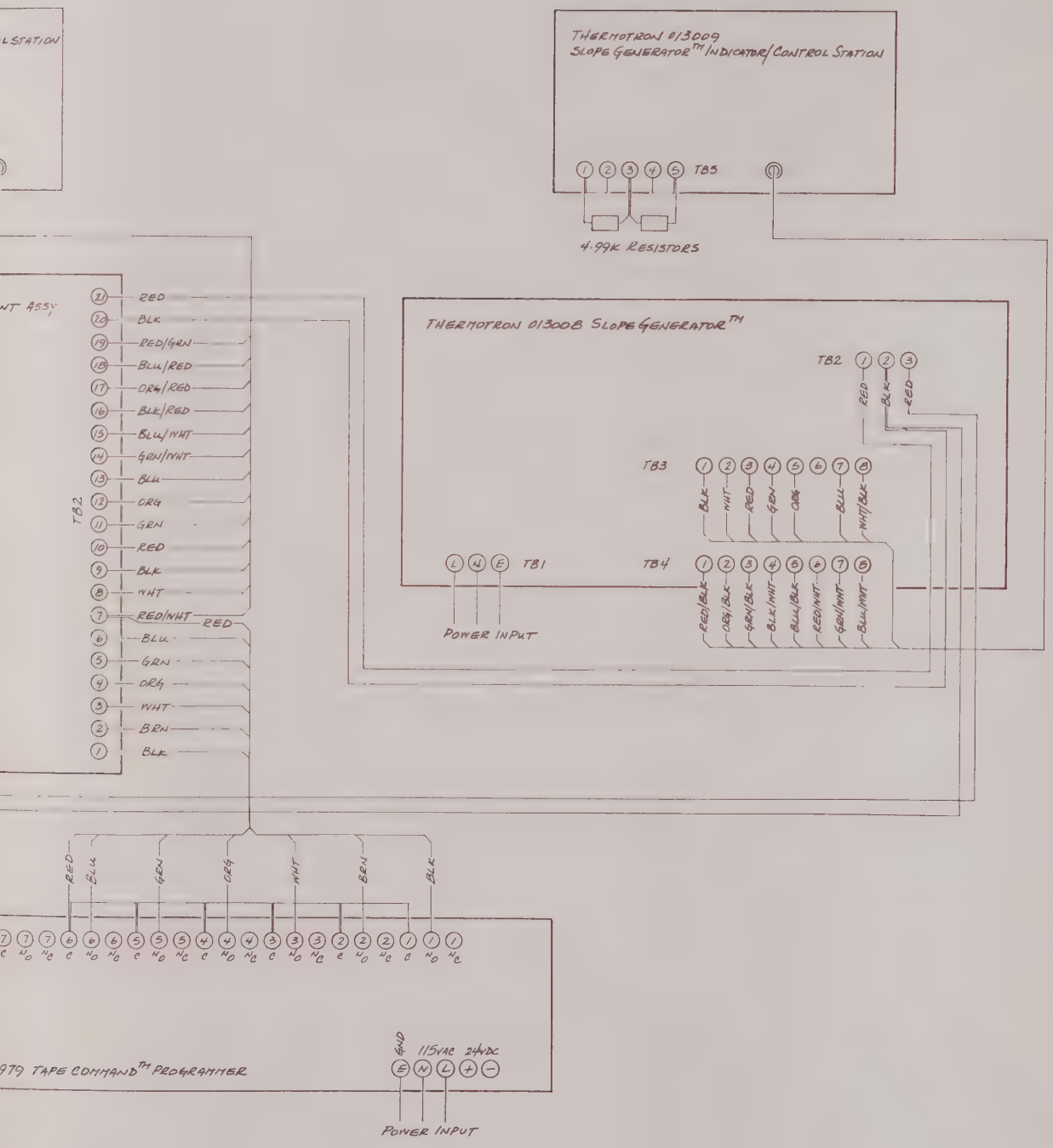
THERMOTRON
151002 SENSOR
(THERMOCOUPLE TYPE T)



THERMOTRON
HOLLAND, MICH. USA

NOTES:

1. CABLES REQUIRED BUT NOT SUPPLIED:
   (RECOMMENDED TYPE - LENGTH TO SUIT
   A. CONTROLLER TO S.S. SWITCHES - BELD
   B. CONTROLLER TO S.P. I/C STATION
   C. CONTROLLER TO SLOPE GENERATOR
   D. S.P. ASSY TO SLOPE GENERATOR
   E. S.P. ASSY TO TAPE COMMAND - BELDEN
2. THREE FOOT CABLES ARE PROVIDED WITH
3. IF SLOPE GENERATOR IS NOT USED CONTR
   CONNECTS TO S.P. ASSY. TB2-20 & TB2



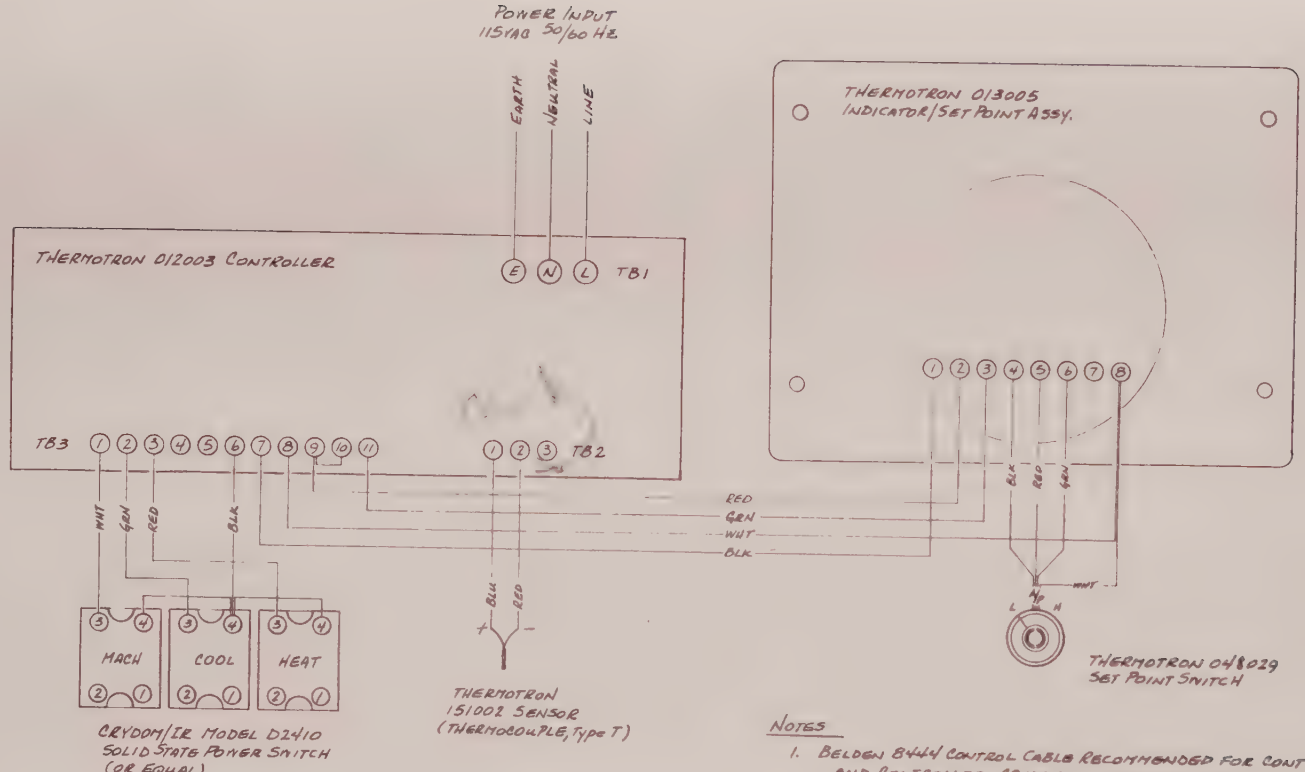
STALLATION)
B444 (4-CONDUCTOR)
ELDEN 8442 (2 CONDUCTOR)
30 (7-CONDUCTOR)
013007 & 013008
GR TB3-7 & TB3-8
(OBSERVE COLOR CODE).

TYPICAL PROGRAMMED CONTROL SYSTEM
WIRING INFORMATION

REF: 012003

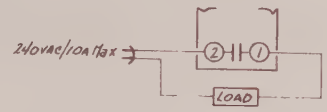
470271

Rev #1: 16 APL 73 GW ADDED 1979 PGMR.



NOTES

1. BELDEN 8444 CONTROL CABLE RECOMMENDED FOR CONTROLLER-INDICATOR AND CONTROLLER-CRYDOM INTERCONNECTIONS.



TYPICAL CRYDOM WIRING

THERMOTRON CORPORATION
HOLLAND, MICHIGAN 49423

NO	CHANGED	DATE	BY	CHKD
NO	CHANGED	DATE	BY	CHKD

TOLERANCE —
SCALE —
MATERIAL AS NOTED
FINISH —
DRAWN BY WARNER DATE 2 NOV 79
CHECKED BY DATE
RELEASED BY DATE

DESCRIPTION
TYPICAL NON-PROGRAMMED CONTROL SYSTEM WIRING INFORMATION
REF: 012003

470269

MANUFACTURING, OPERATION & SERVICE PROCEDURES

for the

013006/013007 SET POINT SYSTEM

HOW TO OPERATE

the

013006/013007 SET POINT SYSTEM

GENERAL DESCRIPTION

The 013006/013007 Set Point System may be looked upon as if it were simply a programmable zero to five volt power supply. The purpose of this equipment is to provide set point instructions for electronic controllers; specifically, temperature controllers.

The system consists of two 'black boxes':

013006 Set Point Assembly
013007 Set Point Indicator/Control Station

The 013006 unit contains all the electronics of the system, and the 013007 unit is its control panel.

The system provides six adjustable set point stations. Any one of these can be connected to its output, at the direction of a remote programming device.

Six digital dials on the control panel may be used to preset these set points at the desired operating points, which may then be selected in sequence by the remote programmer. In this manner, the equipment being controlled can be automatically cycled thru a prescribed operating profile.

The control panel also includes a digital set point indicator, a deviation meter and a switch which permits manual intervention during programmed operation. The set point indicator tells which set point is currently directing the process, and the deviation meter shows where the process is operating, with respect to the set point.

The system includes a failsafe feature, which guards aginst programmer failure and improper programming. This feature allows the programmer to call for one, and only one, set point, at any given time. If two instructions are received simultaniously, or if the signal from the programmer is lost, the output will be directed to a preset safeoperating level until the fault is cleared. This seventh set point adjustment is located inside of the 013006 unit.

In some applications, the 'front panel' features of the system may not be needed, and might not be desired. When this is the case, the 013006 unit will include six additional trimming potentiometers which can be pre-calibrated to the desired operating points, and the 013007 unit will not be provided.

HOW TO PROGRAM THE SET POINT SYSTEM

The system will accept either voltage or contact-closure program instructions from remote programmers. Although six set points are provided, they need not all be programmed. But the remote programmer must have one channel available for each set point that will be used.

PROGRAMMERS WITH VOLTAGE OUTPUTS:

The set point system will accept 0v/+5v signals from programmers of this type. The 0v level will be interpreted as an OFF instruction, and the +5v level will be interpreted as an ON instruction. The tolerances on these levels are:

OFF:	0v ±0.25v
ON:	+5v ±1v

The outputs of the programmer should be connected to TB2 of the 013006 unit, terminals 1 thru 6. These terminal numbers correspond to the set point dials or adjustments, which are also numbered 1 thru 6. A common wire from the programmer should be connected to TB2, terminal 9.

PROGRAMMERS WITH CONTACT OUTPUTS:

When programmed by equipment of this type, the set point system will interpret an open contact as an OFF instruction, and a closed contact as an ON instruction.

Since very little voltage and current is used in conjunction with these contacts, they should be of some type which is suited to low level signals, or 'dry circuit' switching. Gold plated bifurcated contacts would be ideal, in the interest of good reliability.

One side of each output contact should be connected to TB2, terminals 1 thru 6, inside of the 013006 unit. These terminal numbers identify the set point station which will be activated by each contact. The opposite sides of these contacts should all be wired to terminal 7 of TB2, which provides the sensing power.

PROGRAMMING:

Simply configurate your programmer such that at least one of the set points is on at all times, and so that no more than one will ever be on at the same time. In other words, program the system so that at the desired interval two things happen; (1) the current set point will be switched off, and (2) the next set point will be switched on.

Since the set point system will interpret no instruction and more than one instruction as a fault, the sequence of this switching action is not important. However, it should be completed within less than one second so that it will not disturb the process (during the interval between the off and on instructions, the set point system will switch to its failsafe set point).

It is not necessary to select the set points in 1–2–3 order. You may start with any set point station, and sequence from one to another in any order you wish.

A switch on the front of the control panel allows manual intervention at any time during programmed operation. To take over manually, you would simply switch from 'REMOTE' to '1'. When this is done, the output will be connected to Set Point Station 1, and the set point system will ignore the instructions received from the programmer. You may then control the operating point of the equipment manually from Station 1, without interferance by the programmer.

In connection with this manual feature, you might not want to use Set Point Station 1 as a programmed set point when you do not need all six stations for programmed operation.

UNUSED SET POINTS

If you don't need as many as six programmed set points, you might not want to connect all six to your programmer. This would leave more programmer channels available for other functions, or perhaps your programmer does not have enough channels to operate all six set point stations.

In this case, it is good practice to wire the unused program inputs to ground (terminal 9) in the 013006 unit. This will preclude any possibility of electrical interferance intermittantly triggering these unused inputs. For instance, if you don't want to use Set Point Stations 4,5 & 6, jumper wire terminals 4, 5 and 6 to terminal 9, on TB2 inside of the 013006 unit.

HOW TO ADJUST THE SET POINT DIALS

The purpose of the set point system is to provide electronic controllers with set point instructions. The term 'set point' means the point at which we want the controller to stabilize the process. For instance, if we want a temperature controller to hold the temperature at +160F, then we would provide it with some sort of instruction that, to it, would mean '+160F'.

For an electronic controller, this instruction must be presented in some electrical form which is analogous to the temperature range. This is easy to do, because we can simply say . . .

"0v to +5.0v will mean –125F to +375F"

. . . or whatever the range of the controller is. The above range is standard for many of the units manufactured by Thermotron, but any range could be accomodated in this manner. The 0v/+5v electrical signal is referred to as an 'analog of temperature'. Most all Thermotron devices are designed to deal with five volt analogs for the sake of computer compatability, this signal level having become, more or less, standard in that industry.

Generally speaking, a set point instruction of +2.5v would be analogous to a temperature of +125Funder the above convention. But there's a problem.

Because of its fast response capabilities, a thermocouple makes a good temperature sensor for control applications, where sensor response must be fast in order to achieve good control. A thermocouple developes a small electrical signal which is analogous to temperature, but this signal (or analog) is not linear. For instance, its signal may change ±17uv per degree at -125F, but ±30uv per degree at +375F.

At –125F, the thermocouple output is –3.006mv, and at +375F its output is +8.787mv. Within the controller, this low level signal is amplified to more useable levels, and rescaled so that the temperature measuring analog becomes:

0v to +5.0v = –125F to +375F

Since the thermocouple signal was nonlinear, this new analog will also be nonlinear. As a result, +2.5v actually represents +157.5F, insted of +125F.

In operation, the controller will do whatever is necessary to match the temperature measuring analog with the set point analog. Hence, if the set point analog is set at +2.5v, the resulting temperature will be +157.5F. Obviously, neither the set point analog or the temperature measuring analog is very accurate, because the sensor does not provide a linear output signal. In fact, both the set point signal and the temperature measuring signal are representative of the sensors output signal . . . not analogs of temperature in terms of degrees F, but analogs of temperature in terms of the sensor's output signal.

In order to develop an accurate analog of temperature in terms of degrees F, it would be necessary to linearize the thermocouples output signal. Over a 500F temperature span (--125F to +375F), it would be very difficult and expensive to do this with a high degree of accuracy.

The alternative is to find a convenient way to use the analog in its present form.

To provide this convenience, we've prepared tables which relate set point dial settings to both degrees F and degrees C, in one degree incriments:

% SPAN TABLES

The '% Span' expression relates to both the thermocouple's output signal and the voltage analog of that signal. This number can be calculated quite accurately, as will be demonstrated below.

The numbers appearing in the window of the digital set point knobs are a direct read-out of the set point value, in terms of % Span.

In order to adjust a set point station to any desired temperature within the range of –125F to +375F (–87C to +190C), find that temperature on the '% SPAN TABLES'. Then set the set point knob to the number given on the tables which corresponds to the desired temperature.

Example: +160F = .5057

Thus, the set point dial should be set just shy of '506'

HOW TO CALCULATE '% SPAN':

When calculating the percent of span, four systems of engineering units are involved in the problem:

Units	Low End	Mid Pt	High End	Span
percent of span	0%	50%	100%	100%
sensor millivolts*	–3.006mv	+2.891mv	+8.787mv	11.793mv
analog volts	0v	+2.500v	+5.000v	+5.000v
degrees F	–125F	+157.5F	+375F	500F

(*) Copper vs Constantan, type T, thermocouple

The problem is, to relate 'percent of span' to degrees F. In order to do this, we must first find out what the sensor's output will be at the temperature of interest, and then compare this aginst its total output change over the entire –125F to +375F temperature range. This yields the '% Span' figure. This figure can be multiplied by five, to determine the analog voltage corresponding to this specific operating point.

Example: To find the % Span and analog voltage which corresponds to +160F

1. Referring to the thermocouple calibration table, Copper vs Constantan, we find that the sensor's output at +160F is:

   +2.958mv

2. It's output at the low end of our range (–125F) is –3.006mv, so its total output change from –125F to +160F is:

   $$\begin{array}{r} 3.006\text{mv} \\ +\ 2.958\text{mv} \\ \hline 5.964\text{mv} \end{array}$$

3. Over the entire –125F to +375F range, the output span of the sensor is:

   $$\begin{array}{rl} 3.006\text{mv} & \textit{(–125F)} \\ +\ 8.787\text{mv} & \textit{(+375F)} \\ \hline 11.793\text{mv} & \end{array}$$

4. The sensor's output at +160F, in terms of percent, is:

   $$\frac{5.964\text{mv}}{11.793\text{mv}} = .5057237, \text{ or } \underline{\underline{50.57\%}}$$

5. The analog voltage corresponding to +160F is therefore:

   $$\begin{array}{r} +5.000\text{v} \\ \times\ .5057 \\ \hline +2.529\text{v} \end{array}$$

HOW TO OPERATE THE SYSTEM MANUALLY

On the front of the control panel of the set point system there is a switch labeled '1' – 'REMOTE'. During programmed operation, this switch must be set at the 'REMOTE' position. When set in this position, the set point system will accept instructions from the remote programmer.

The switch is equipped with a latching toggle, which prevents accidental changes of its position.

In order to operate the system manually, gently pull the switch toggle toward you, then move it to the '1' position. The set point indicator will change to '1', and the set point system will now disregard any further instructions from the remote programmer. You may now operate the system from Set Point Station 1. When you wish to return to programmed

operation, simply return the toggle to the 'REMOTE' position.

HOW TO READ THE DEVIATION METER

The deviation meter tells where the operating point is with respect to the set point.

This indicator receives its signal from the controller, which electronically calculates the differance, and not from the set point system circuitry.

When the indicator pointer is at the exact middle of the scale, the null point, it means that the operating point is the same as the set point: no deviation.

To the left of the null point is a green band, and to the right is an orange band. When the pointer is in the green band, it means that the operating point is lower than the set point; in the orange band it means that the operating point is too high.

The meter scale is divided into five incriments to either side of the null point. Within the controller, there is an adjustment which controlls the sensitivity of this meter. The normal setting of this adjustment is ±5%. At this setting, each incriment on the deviation meter is equal to 1%, so its full-scale range is –5% to +5% of span.

For the 500F (–125F to +375F) temperature range, 1% is about equal to 5 degrees F *(subject to the nonlinearity of the thermocouple sensor)*, so for this range, one incriment is about equal to 5 degrees F.

The 'DEV SPAN' adjustment in the controller may be set for any sensitivity between ±0% and ±5%. Before you can read the deviation meter, you must know the setting of this adjustment.

FIELD CALIBRATION PROCEDURES

for

SET POINT SYSTEM 013006/013007

PRELIMINARY INFORMATION

The 013006/013007 Set Point System has five adjustments which should be checked periodically in order to assure that the system is operating properly and accurately.

In those cases where the 013006 Set Point Assembly is used without the 013007 Set Point Indicator/Control Assembly, the 013006 unit will also include six set point adjustments which must be preset at the desired operating points.

The only equipment required in order to do these adjustments is an accurate digital voltmeter (DVM). A good digital voltmeter (Fluke Model 8000A, or equal) should always be used, insted of a VOM or VTVM, because the accuracy of the latter types seldom exceeds one or two percent.

WARNING

An electrical potential of 115 volts AC at 50-60 Hz is present on the circuit board of the 013006 Set Point Assembly, in the area of the transformer and the terminal block marked TB1. Keep your hands and tools away from this area. Should any part of your body come into contact with this potential, you might be seriously injured, directly or indirectly, as a result of

ELECTRICAL SHOCK

In the remaining areas of the circuit board low DC voltages [less than 30vdc] are less hazardous to life, however short circuiting these potentials might result in permanent damage to the equipment. So be careful when useing screwdrivers and test probes.

EQUIPMENT SAFETY

In the following procedure, take whatever steps that are necessary in order to . . .

POSITIVELY DISABLE THE EQUIPMENT

. . . that is normally controlled according to the set points produced by this system. This will assure that such equipment is not inadvertantly operated at unsafe levels during this calibration procedure.

1. POWER SUPPLY ADJUSTMENTS

The set point unit's power supply includes a +15v regulated supply and a −15v regulated supply. These two supplies are used to provide referance voltages at several points in the set point circuitry, so it is important that they be properly adjusted.

1.1. Remove the cover from the 013006 Set Point Assy by pushing its ends in gently, and pulling it straight up off of the chassis.

1.2. Connect the DVM [+] lead to R44 (brown-grey-gold-gold) on the end marked [+]. Connect the DVM [−] lead to TB2, terminal 9.

1.3. The DVM indication should now be +15.00v. If not, adjust R39 as necessary to provide this indication. R39 is adjacent to IC13.

1.4. Now connect the [+] lead of the DVM to the case of IC 3.

1.5. The DVM indication should now be −15.00v. If not, adjust R41 as necessary to produce this reading. R41 is adjacent to IC14.

2. SET POINTS CALIBRATION

This part of the procedure applies only to those systems which include the 013007 Set Point Indicator/Control Station. Its purpose is to calibrate the set point dials so that their digital read-outs will be accurate in terms of percent of span.

2.1. Connect the DVM [+] lead to TB2, terminal 21, and its [−] lead to TB2, terminal 20.

2.2. Move the switch on the set point control panel to the '1' position (up).

2.3. Turn the dial at Set Point Station 1 in the clockwise direction until it reaches the clockwise limit. Then turn the dial counterclockwise about $1/10^{th}$ of a turn to produce a digital indication of exactly 000−.

2.4. At this time, the DVM indication should be +5.00v exactly. If not, adjust R36 to produce this indication. R36 is located next to IC12 on the 013006 circuit board.

2.5. Now set 'Station 1' to the settings listed below and verify that the correct output is provided at each point. If desired, you may then trim the setting of R36 as required to optomize the accuracy over the entire span.

Dial Setting	DVM Indication
000 (cw)	+5.000v
800	+4.000
600	+3.000
400	+2.000
200	+1.000

3. SET POINT ADJUSTMENTS

This part of the procedure applies only to those systems which do not include the 013007 Set Point Indicator/Control Station. Its purpose is to preset the set point adjustments at the desired operating points.

3.1. Connect the DVM [+] lead to TB2, terminal 21, and its [–] lead to TB2, terminal 20.

3.2. Notice the seven trimming potentiometers which are located adjacent to the terminal block, marked 'SET POINTS'. The set point potentiometers are numbered 1 thru 6. The seventh adjustment is the failsafe set point adjustment, which will be adjusted later.

3.3. If you can conveniently operate the outputs of your remote programmer, you may use it to provide the set point instructions which are called for below. Otherwise, disconnect temporarily any wires which are connected to TB2, terminals 1 thru 6.

3.4. Refer to the '% SPAN TABLES' and calculate the value of the analog voltage for each one of your desired operating points. For example:

+160F = .5057 x 5v = 2.5285v
– 65F = .0895 x 5v = 0.4475v

. . . etc

3.5. To activate set points 1 thru 6, connect +5v from TB2, terminal 7, to terminals 1,2,3,4,5 & 6, one at a time. At each point, adjust the corresponding set point potentiometer so that the DVM indication is the same as the value which you calculated for that operating point in step 3.4.

3.6. When finished, reconnect any wires that were disconnected from TB2, terminals 1 thru 6 in step 3.3.

NOTE

If one of your voltage settings is higher than you can achieve by adjusting the set point adjustment (but not more than +5v)

turn the set point adjustment clockwise until the DVM indication stops increasing. Then turn R36 (adjacent to IC12) clockwise until the DVM indication is +5.00v. You may then readjust the set point to the desired operating point.

WARNING

Whenever you change the setting of R36, all of the set point adjustments will be effected. They should therefore all be readjusted to the proper operating points.

4. FAILSAFE SET POINT ADJUSTMENT

The failsafe set point will be activated when the remote programming signals are improper, and when no programming signals are received, unless the system is set for manual operation. The failsafe set point should be set to a safe operating point for the equipment which is being controlled. In temperature control systems, this set point is usually set at +75F, so that the equipment will be brought back to room temperature in the event of a programming fault.

4.1. Connect the DVM [+] lead to TB2, terminal 21, and its [–] lead to terminal 20.

4.2. Determine which set point is currently ON, then short the like-numbered terminal on TB2 to any one of the other program inputs, terminals 1 thru 6. For example, if set point 3 is now on, short terminal 3 to terminal 2 or terminal 4.

4.3. If the system includes a 013007 Set Point Indicator/Control Station, the set point indicator on the panel should now display the number '7'.

4.4 Refer to the '% SPAN TABLES' and calculate the analog voltage level which corresponds to a safe operating point for the equipment being controlled. For example:

+75F = .3352 x 5v = 1.676v

4.5. On the 013006 circuit board, find the failsafe set point adjustment, under the legend 'SET POINTS'. This adjustment is labeled '7'. Turn this adjustment as required to set the DVM reading at the value which was calculated above, in step 4.4.

PRELIMINARY INFORMATION

The 013006 Set Point Assembly is a precision device. As such, it includes several adjustments which serve to set circuit values to within closer tolerances than can be achieved through the selection of standard fixed componet values.

This procedure is intended for factory production and test, factory service, and bench level service at field repair stations. Units which can successfully meet these minimum performance requirements can be considered to be fully serviceable, and able to perform their designed functions within the limits of their specification.

EQUIPMENT REQUIRED

1. Digital Voltmeter, Fluke Model 8000A, or equal.
   [Do not use a VOM or VTVM, since the accuracy of analog type meters is not satisfactory for this procedure.]
2. Oscilloscope, Tektronix 212, or equal.
3. Resistor, 330 Ohms, ¼w, 5%
4. Resistor, 150 Ohms, ¼w, 5%
5. Variac, Superior Electric 116B, or equal.

COPPER vs. COPPER-NICKEL

(Copper-Constantan)

TYPE T

Temperature in Degrees F

Reference Junction at 32°F

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
-190	-4.009	-4.023	-4.037	-4.051	-4.065	-4.079	-4.093	-4.107	-4.121	-4.135	-4.149	-190
-180	-3.864	-3.879	-3.894	-3.908	-3.923	-3.937	-3.951	-3.966	-3.980	-3.994	-4.009	-180
-170	-3.717	-3.732	-3.746	-3.761	-3.776	-3.791	-3.806	-3.820	-3.835	-3.850	-3.864	-170
-160	-3.565	-3.580	-3.596	-3.611	-3.626	-3.641	-3.656	-3.671	-3.687	-3.702	-3.717	-160
-150	-3.410	-3.425	-3.441	-3.457	-3.472	-3.488	-3.503	-3.519	-3.534	-3.550	-3.565	-150
-140	-3.251	-3.267	-3.283	-3.299	-3.315	-3.331	-3.347	-3.362	-3.378	-3.394	-3.410	-140
-130	-3.089	-3.105	-3.121	-3.138	-3.154	-3.170	-3.186	-3.203	-3.219	-3.235	-3.251	-130
-120	-2.923	-2.939	-2.956	-2.973	-2.989	-3.006	-3.023	-3.039	-3.056	-3.072	-3.089	-120
-110	-2.753	-2.771	-2.788	-2.805	-2.822	-2.838	-2.855	-2.872	-2.889	-2.906	-2.923	-110
-100	-2.581	-2.598	-2.616	-2.633	-2.650	-2.667	-2.685	-2.702	-2.719	-2.736	-2.753	-100
-90	-2.405	-2.422	-2.440	-2.458	-2.475	-2.493	-2.511	-2.528	-2.546	-2.563	-2.581	-90
-80	-2.225	-2.243	-2.261	-2.279	-2.297	-2.315	-2.333	-2.351	-2.369	-2.387	-2.405	-80
-70	-2.042	-2.061	-2.079	-2.098	-2.116	-2.134	-2.152	-2.171	-2.189	-2.207	-2.225	-70
-60	-1.856	-1.875	-1.894	-1.912	-1.931	-1.950	-1.968	-1.987	-2.005	-2.024	-2.042	-60
-50	-1.667	-1.686	-1.705	-1.724	-1.743	-1.762	-1.781	-1.800	-1.819	-1.838	-1.856	-50
-40	-1.475	-1.494	-1.513	-1.533	-1.552	-1.571	-1.591	-1.610	-1.629	-1.648	-1.667	-40
-30	-1.279	-1.299	-1.319	-1.338	-1.358	-1.377	-1.397	-1.416	-1.436	-1.455	-1.475	-30
-20	-1.081	-1.101	-1.121	-1.141	-1.160	-1.180	-1.200	-1.220	-1.240	-1.260	-1.279	-20
-10	-0.879	-0.899	-0.920	-0.940	-0.960	-0.980	-1.000	-1.021	-1.041	-1.061	-1.081	-10
0	-0.674	-0.695	-0.716	-0.736	-0.757	-0.777	-0.798	-0.818	-0.838	-0.859	-0.879	0
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
0	-0.674	-0.654	-0.633	-0.613	-0.592	-0.571	-0.550	-0.529	-0.509	-0.488	-0.467	0
10	-0.467	-0.446	-0.425	-0.404	-0.383	-0.362	-0.341	-0.320	-0.299	-0.277	-0.256	10
20	-0.256	-0.235	-0.214	-0.193	-0.171	-0.150	-0.129	-0.107	-0.086	-0.064	-0.043	20
30	-0.043	-0.022	0.000	0.022	0.043	0.065	0.086	0.108	0.130	0.151	0.173	30
40	0.173	0.195	0.216	0.238	0.260	0.282	0.303	0.325	0.347	0.369	0.391	40
50	0.391	0.413	0.435	0.457	0.479	0.501	0.523	0.545	0.567	0.589	0.611	50
60	0.611	0.634	0.656	0.678	0.700	0.722	0.745	0.767	0.789	0.812	0.834	60
70	0.834	0.857	0.879	0.902	0.924	0.947	0.969	0.992	1.014	1.037	1.060	70
80	1.060	1.082	1.105	1.128	1.151	1.173	1.196	1.219	1.242	1.265	1.288	80
90	1.288	1.311	1.334	1.357	1.380	1.403	1.426	1.449	1.472	1.495	1.518	90
100	1.518	1.542	1.565	1.588	1.611	1.635	1.658	1.681	1.705	1.728	1.752	100
110	1.752	1.775	1.799	1.822	1.846	1.869	1.893	1.917	1.940	1.964	1.988	110
120	1.988	2.011	2.035	2.059	2.083	2.107	2.131	2.154	2.178	2.202	2.226	120
130	2.226	2.250	2.274	2.298	2.322	2.347	2.371	2.395	2.419	2.443	2.467	130
140	2.467	2.492	2.516	2.540	2.565	2.589	2.613	2.638	2.662	2.687	2.711	140
150	2.711	2.736	2.760	2.785	2.809	2.834	2.859	2.883	2.908	2.933	2.958	150
160	2.958	2.982	3.007	3.032	3.057	3.082	3.107	3.131	3.156	3.181	3.206	160
170	3.206	3.231	3.256	3.281	3.307	3.332	3.357	3.382	3.407	3.432	3.458	170
180	3.458	3.483	3.508	3.533	3.559	3.584	3.609	3.635	3.660	3.686	3.711	180
190	3.711	3.737	3.762	3.788	3.813	3.839	3.864	3.890	3.916	3.941	3.967	190
200	3.967	3.993	4.019	4.044	4.070	4.096	4.122	4.148	4.174	4.199	4.225	200
210	4.225	4.251	4.277	4.303	4.329	4.355	4.381	4.408	4.434	4.460	4.486	210
220	4.486	4.512	4.538	4.565	4.591	4.617	4.643	4.670	4.696	4.722	4.749	220
230	4.749	4.775	4.801	4.828	4.854	4.881	4.907	4.934	4.960	4.987	5.014	230
240	5.014	5.040	5.067	5.093	5.120	5.147	5.174	5.200	5.227	5.254	5.281	240
250	5.281	5.307	5.334	5.361	5.388	5.415	5.442	5.469	5.496	5.523	5.550	250
260	5.550	5.577	5.604	5.631	5.658	5.685	5.712	5.739	5.767	5.794	5.821	260
270	5.821	5.848	5.875	5.903	5.930	5.957	5.985	6.012	6.039	6.067	6.094	270
280	6.094	6.122	6.149	6.177	6.204	6.232	6.259	6.287	6.314	6.342	6.369	280
290	6.369	6.397	6.425	6.452	6.480	6.508	6.536	6.563	6.591	6.619	6.647	290
300	6.647	6.675	6.702	6.730	6.758	6.786	6.814	6.842	6.870	6.898	6.926	300
310	6.926	6.954	6.982	7.010	7.038	7.066	7.094	7.122	7.151	7.179	7.207	310
320	7.207	7.235	7.263	7.292	7.320	7.348	7.377	7.405	7.433	7.462	7.490	320
330	7.490	7.518	7.547	7.575	7.604	7.632	7.661	7.689	7.718	7.746	7.775	330
340	7.775	7.804	7.832	7.861	7.889	7.918	7.947	7.975	8.004	8.033	8.062	340
350	8.062	8.090	8.119	8.148	8.177	8.206	8.235	8.264	8.292	8.321	8.350	350
360	8.350	8.379	8.408	8.437	8.466	8.495	8.524	8.553	8.583	8.612	8.641	360
370	8.641	8.670	8.699	8.728	8.757	8.787	8.816	8.845	8.874	8.904	8.933	370
380	8.933	8.962	8.992	9.021	9.050	9.080	9.109	9.139	9.168	9.198	9.227	380
390	9.227	9.257	9.286	9.316	9.345	9.375	9.404	9.434	9.464	9.493	9.523	390
400	9.523	9.553	9.582	9.612	9.642	9.671	9.701	9.731	9.761	9.791	9.820	400
410	9.820	9.850	9.880	9.910	9.940	9.970	10.000	10.030	10.060	10.090	10.120	410
420	10.120	10.150	10.180	10.210	10.240	10.270	10.300	10.330	10.360	10.390	10.420	420
430	10.420	10.451	10.481	10.511	10.541	10.572	10.602	10.632	10.662	10.693	10.723	430
440	10.723	10.753	10.784	10.814	10.845	10.875	10.905	10.936	10.966	10.997	11.027	440
450	11.027	11.058	11.088	11.119	11.149	11.180	11.211	11.241	11.272	11.302	11.333	450
460	11.333	11.364	11.394	11.425	11.456	11.487	11.517	11.548	11.579	11.610	11.640	460
470	11.640	11.671	11.702	11.733	11.764	11.795	11.826	11.856	11.887	11.918	11.949	470
480	11.949	11.980	12.011	12.042	12.073	12.104	12.135	12.166	12.198	12.229	12.260	480
490	12.260	12.291	12.322	12.353	12.384	12.416	12.447	12.478	12.509	12.540	12.572	490
500	12.572	12.603	12.634	12.666	12.697	12.728	12.760	12.791	12.822	12.854	12.885	500
510	12.885	12.917	12.948	12.979	13.011	13.042	13.074	13.105	13.137	13.168	13.200	510
520	13.200	13.232	13.263	13.295	13.326	13.358	13.390	13.421	13.453	13.485	13.516	520
530	13.516	13.548	13.580	13.611	13.643	13.675	13.707	13.739	13.770	13.802	13.834	530
540	13.834	13.866	13.898	13.930	13.961	13.993	14.025	14.057	14.089	14.121	14.153	540
550	14.153	14.185	14.217	14.249	14.281	14.313	14.345	14.377	14.409	14.441	14.474	550
560	14.474	14.506	14.538	14.570	14.602	14.634	14.666	14.699	14.731	14.763	14.795	560
570	14.795	14.828	14.860	14.892	14.924	14.957	14.989	15.021	15.054	15.086	15.118	570
580	15.118	15.151	15.183	15.216	15.248	15.280	15.313	15.345	15.378	15.410	15.443	580
590	15.443	15.475	15.508	15.540	15.573	15.605	15.638	15.671	15.703	15.736	15.769	590
600	15.769	15.801	15.834	15.866	15.899	15.932	15.965	15.997	16.030	16.063	16.096	600
610	16.096	16.128	16.161	16.194	16.227	16.259	16.292	16.325	16.358	16.391	16.424	610
620	16.424	16.457	16.490	16.523	16.555	16.588	16.621	16.654	16.687	16.720	16.753	620
630	16.753	16.786	16.819	16.852	16.886	16.919	16.952	16.985	17.018	17.051	17.084	630
640	17.084	17.117	17.150	17.184	17.217	17.250	17.283	17.316	17.350	17.383	17.416	640
650	17.416	17.450	17.483	17.516	17.549	17.583	17.616	17.649	17.683	17.716	17.750	650
660	17.750	17.783	17.816	17.850	17.883	17.917	17.950	17.984	18.017	18.051	18.084	660
670	18.084	18.118	18.151	18.185	18.218	18.252	18.285	18.319	18.353	18.386	18.420	670
680	18.420	18.454	18.487	18.521	18.555	18.588	18.622	18.656	18.689	18.723	18.757	680
690	18.757	18.791	18.824	18.858	18.892	18.926	18.960	18.993	19.027	19.061	19.095	690
700	19.095	19.129	19.163	19.197	19.230	19.264	19.298	19.332	19.366	19.400	19.434	700
710	19.434	19.468	19.502	19.536	19.570	19.604	19.638	19.672	19.706	19.740	19.774	710
720	19.774	19.808	19.843	19.877	19.911	19.945	19.979	20.013	20.047	20.081	20.116	720
730	20.116	20.150	20.184	20.218	20.252	20.287	20.321	20.355	20.389	20.423	20.458	730
740	20.458	20.492	20.526	20.560	20.595	20.629	20.663	20.698	20.732	20.766	20.801	740
750	20.801	20.835	20.869									750
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F

* CONVERTED FROM DEGREES CELSIUS (1968).

TYPE T

NEW REFERENCE TABLES
SUPERSEDES N.B.S. CIRCULAR #561

ALLIGNMENT, CALIBRATION & MINIMUM PERFORMANCE CHECKS

for

SET POINT ASSEMBLY 013006

GENERAL PROCEDURE

This procedure works through the circuitry of the Set Point Assembly in the following order:

1. D.C. POWER SUPPLY & REGULATOR CIRCUITS
2. FAILSAFE DETECTOR CIRCUITS
3. BINARY ENCODER CIRCUITS
4. SET POINT MULTIPLEXER & OUTPUT CKTS

In general, this order should be adhered to since the results that are to be achieved in a given section may be contingent upon having properly completed some procedure in a previous section.

After completing each segment of the procedure, the set up for that segment should be removed, unless the next segment calls for it to be retained.

Line power should be applied to terminals L, N and E of TB1 [Line, Neutral and Earth] from the variac, which should be set at 115vac unless otherwise specified in the procedure.

Unless otherwise specified, terminals 4 and 7 of TB2 are to be jumpered togather during all tests. This is especially important in connection with the power supply checks, where incorrect readings may result if this rule is not followed.

A 013007 Set Point Indicator/Control Station must be connected to the 013006 Set Point Assembly during this procedure. Wiring information is given on drawing 470271. This switch on the 013007 unit must be set at 'REMOTE', unless otherwise specified. The set point dials should be set as follows:

Set Point 1	200
2	400
3	600
4	800
5	1000
6	0000

1. D.C. POWER SUPPLY & REGULATOR CIRCUITS

The power supply system produces four dc potentials; ±30v unregulated and ±15v regulated. Checks include:

1.1. Unregulated voltage levels
1.2. Regulated voltage levels
1.3. Line regulation
1.4. Load regulation
1.5. Nominal load current
1.6. Current limit operation
1.7. Oscillation, Noise & transient response

1.1. Unregulated Voltage Levels

On TB2, jumper terminal 4 to terminal 7

Connect the DVM [+] lead to IC13-3, and its [–] lead to ground. Set the line voltage at 115vac [variac]. The DVM should indicate +25v, ±4v.

Connect the DVM between IC14-5 and ground. With the line voltage at 115vac, the DVM should indicate –29v ±4v.

1.2. Regulated Voltage Levels

Connect the DVM between IC13-8 and ground. Set the line voltage at 115vac. The DVM should indicate +15.00v. If not, adjust R39 to provide this indication.

Connect the DVM between IC14-8 and ground. With the line voltage at 115vac, the DVM indication should be –15.00v. If not, adjust R41 to produce this indication.

1.3. Line Regulation

Connect the DVM between IC13-8 and ground. The specified line voltage range for the set point system is 90vac to 130vac. As the line voltage is varied between these limits, the DVM indication must remain within the limits of +14.98v to +15.02v.

Connect the DVM between IC14-8 and ground. Repeat the above procedure for the –15v supply. The DVM indication must remain within the limits of –14.98v to –15.02v.

1.4. Load Regulation, Load Current & Current Limit

Connect the DVM across R44. The DVM indication will be about 280mv, ±20mv. This represents a nominal load current of about 156mA.

Connect the DVM between IC13-8 and ground. Connect a 330 ohm resistor between the leads of the DVM. This increases the load current to about 200mA. When this is done, the DVM indication should remain within the limits of +14.98v and +15.02v.

Disconnect the resistor, and connect the DVM across R44. Now short IC13-8 to ground. The DVM indication should now rise to between 345mv and 405mv. This represents a current limit of between 192mA and 225mA.

Leave the short in place, and connect the DVM between IC13-8 and ground. The DVM indication will be about +.01v. When the short is removed, the indication will immediately recover to within the limits of +14.98v and +15.02v.

Connect the DVM across R43. The DVM indication will be about 80mv ±10mv. This represents a nominal load current of about 15mA.

Connect the DVM between IC14-8 and ground. Connect a 150 ohm resistor between the leads of the DVM. This increases the load current to about 100mA. When this is done, the DVM indication should remain within the limits of −14.98v and −15.02v.

Disconnect the resistor, and connect the DVM across R43. Now short IC14-8 to ground. The DVM indication should rise to between 590mv and 690mv. This represents a load current limit of between 115mA and 135mA.

Leave the short in place, and connect the DVM between IC14-8 and ground. The DVM indication will be about −.01v. When the short is removed, the indication will immediately recover to within the limits of −14.98v and −15.02v.

1.5. Oscillation, Noise & Transient Response

Connect the oscilloscope between IC13-8 and ground. The combined amplitude of any oscillation, noise and transient spikes should not exceed 20mv peak to peak.

Connect the oscilloscope between IC14-8 and ground. The same limits apply to this point; the composit signal not exceeding 20mv peak to peak.

2. FAILSAFE DETECTOR CIRCUITS

The failsafe detector circuits monitor the program inputs in order to protect aginst improper programming signals, and the loss of program instructions. Checks include:

2.1. Input conversion levels
2.2. Input summing
2.3. Trip points
2.4. Detector output signal

2.1. Input Conversion Levels

Connect the DVM between IC1-6 and ground.

A jumper wire is already connected between terminals 4 and 7 of TB2. Disconnect the end of this wire that is connected to terminal 4, then alternately touch it to terminals 1,2,3,4,5 and 6. At each point, the DVM must indicate within the range of –4.00v to –6.00v.

2.2. Input Summing

Retaining the above set up, connect the loose end of the jumper wire to TB2, terminals 1 and 2. The DVM indication must now be within the limits of –8.00v to –10.00v.

Now disconnect the wire from terminals 1 and 2. All the terminals from 1 through 6 on TB2 should now be open [no connections]. The DVM indication must now be within the range of –1.0v to +1.0v.

Reconnect the jumper wire between terminals 4 and 7 of TB2.

2.3. Trip Points

Connect the [+] lead of the DVM to IC2-2, and its [–] lead to ground. The DVM indication must now be within the range of –2.25v to –2.75v.

Connect the DVM [+] lead to IC3-3. The DVM indication must now be within the range of –7.25v to –7.75v.

2.4. Detector Output Signal

Connect the [+] lead of the DVM to IC3-6, and its [–] lead to ground. The DVM indication must now be within the range of –0.5v to +0.5v.

Now disconnect the end of the jumper wire from TB2, terminal 4, momentarily. With the wire disconnected, the DVM indication must be within the range +13.5v to +15.0v.

3. BINARY ENCODER CIRCUITS

The binary encoder circuits monitor the program inputs and develop a three bit binary signal, on parallel lines, which tells the set point indicator system which input is active. The following procedure checks the codeing accuracy and logic signal levels.

NOTE

In the following checks, the voltage tolerances are:

0v: +0.4v max
5v: +4.5v min

3.1. Input '0'

Disconnect the jumper wire from TB2, terminal 4. Terminals 1 through 6 of TB2 should now be open.

Connect the DVM [–] lead to ground, and its [+] lead alternately to terminals 11, 12 and 13 of TB2. The DVM indication at each terminal must be +5v.

3.2. Input '1'

Connect the loose end of the jumper wire to TB2, terminal 1.

Connect the DVM [+] lead alternately to terminals 11, 12 and 13 of TB2; then to the transistors as indicated:

TB2-11: 0v	Q4c: +5v
TB2-12: 0v	Q3c: +5v
TB2-13: +5v	Q2c: 0v

3.3. Input '6'

Disconnect the jumper wire from terminal 1, and connect it to terminal 6.

Useing the DVM, verify the following logic levels:

TB2-11: +5v	Q4c: 0v
TB2-12: +5v	Q3c: 0v
TB2-13: 0v	Q2c: +5v

3.4. Input '7'

Retaining the above set up, connect a second jumper wire between terminals 5 and 6.

Connect the [+] lead of the DVM to Q1c. The DVM indication will be 0v.

Now remove the second jumper, so that only terminal 6 is connected to terminal 7 of TB2. The DVM indication will now be +5v.

3.5. Final Code Check

Now disconnect the jumper wire from terminal 6, then, while watching the set point indicator on the 013007 unit, connect the loose end of the jumper wire alternately to terminals 1 through 6 of TB2, and verify that the indicator displays the proper numeral for each connection:

TB2 Connection	Indicator Read-Out
none	7
1	1
2	2
3	3
4	4
5	5
6	6
any two	7

4. SET POINT MULTIPLEXER & OUTPUT CIRCUITS

The set point multiplexer consists of analog gates, which alternately connect the set point adjustments to the output buffer circuit. The following procedure checks the operation of these gates, set point calibration, failsafe operation and offset voltage in the output circuitry.

Connect the DVM between TB2 terminals 20 [–] and 21 [+].

Disconnect the jumper wire from terminal 4 of TB2, then alternately reconnect it as shown below, doing the adjustments as specified and verifying the output values listed:

TB2 Connection	DVM Indication
6	0.000v ±.015v
5	5.000v "

If not, adjust R36 as required to provide this indication.

4	4.000v "
3	3.000v "
2	2.000v "
1	1.000v "
none	1.676v "

If not, adjust R13, 'S.P. 0', to provide this output level.

Reconnect the jumper wire to terminal 4 of TB2, then connect the oscilloscope between terminals 20 and 21 of TB2.

The peak to peak amplitude of any noise, transient spikes or oscillation, as seen on the scope, should not exceed 20mv.

PROCEDURAL VARIATIONS

for

013006 UNITS WITH INTEGRAL SET POINT POTS

GENERAL

When the 013006 Set Point Assembly is to be used without the 013007 Set Point Indicator/Control Station, it will be provided with potentiometers R14 through R19, which are not otherwise installed.

When this is the case, the written procedures must be altered as follows:

1. HOW TO OPERATE . . .

2. FIELD CALIBRATION . . .

   The applicable variations have been included in these procedures.

3. ALLIGNMENT, CALIB.,& MIN PERFORMANCE CKS

   The 013007 unit will not be used in this test. In section 4 of this procedure, the integral set point adjustments should be set to the values listed for that test.

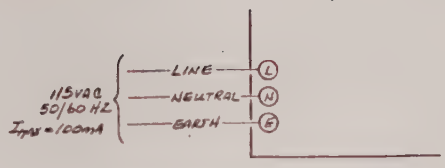
4. BURN IN . . .

   The 013007 unit will not be used in this test. The integral set point adjustments should be set to the values given in section 4 of the Allignment, Calibration and Minimum Performance Checks.

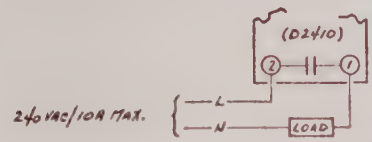
5. FINAL TEST . . .

   The 013007 unit will not be used in this test. The integral set point adjustments should be set to the values given under item 4 of this procedure.

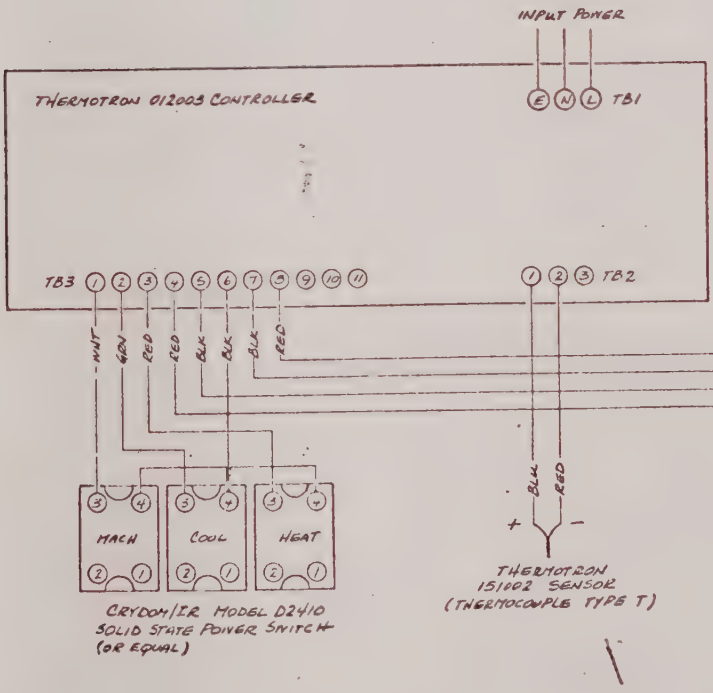
In all cases, those parts of the procedure which call for some action or observation involving the 013007 unit may be omitted.



TYPICAL INPUT POWER CONNECTIONS



TYPICAL OUTPUT CONNECTIONS
(N.O. CIRCUIT)

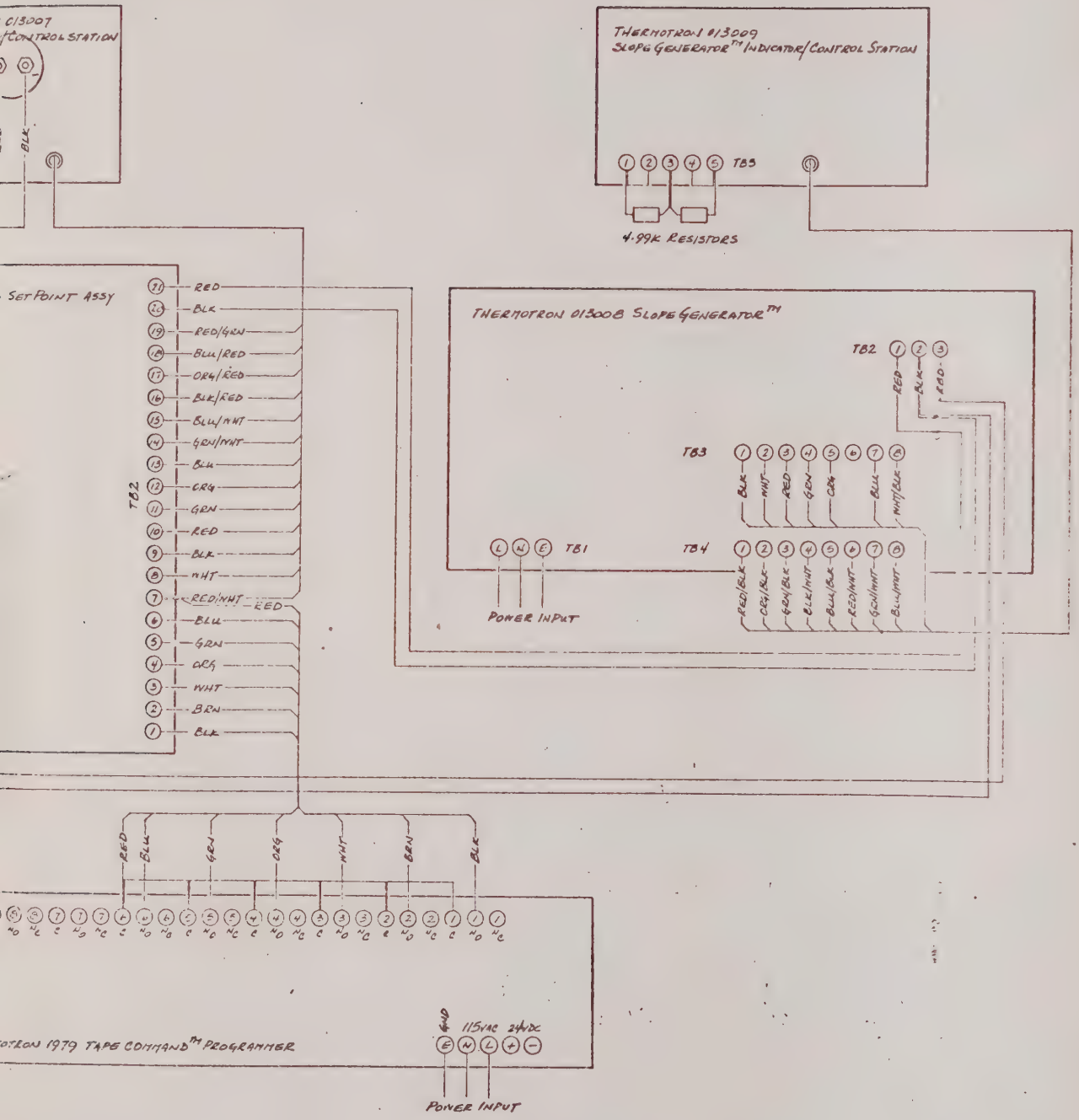


CRYDOM/IR MODEL D2410
SOLID STATE POWER SWITCH
(OR EQUAL)

THERMOTRON
HOLLAND, MICH. USA

NOTES:

1. CABLES REQUIRED BUT NOT
   (RECOMMENDED TYPE - LOW
   A. CONTROLLER TO S.S. SWITCH
   B. CONTROLLER TO S.P. I/C S
   C. CONTROLLER TO SLOPE GEN
   D. S.P. ASSY TO SLOPE GEN
   E. S.P. ASSY TO TAPE COMMAND
2. THREE FOOT CABLES ARE REQ
3. IF SLOPE GENERATOR IS NOT
   CONNECTS TO S.P. ASSY.



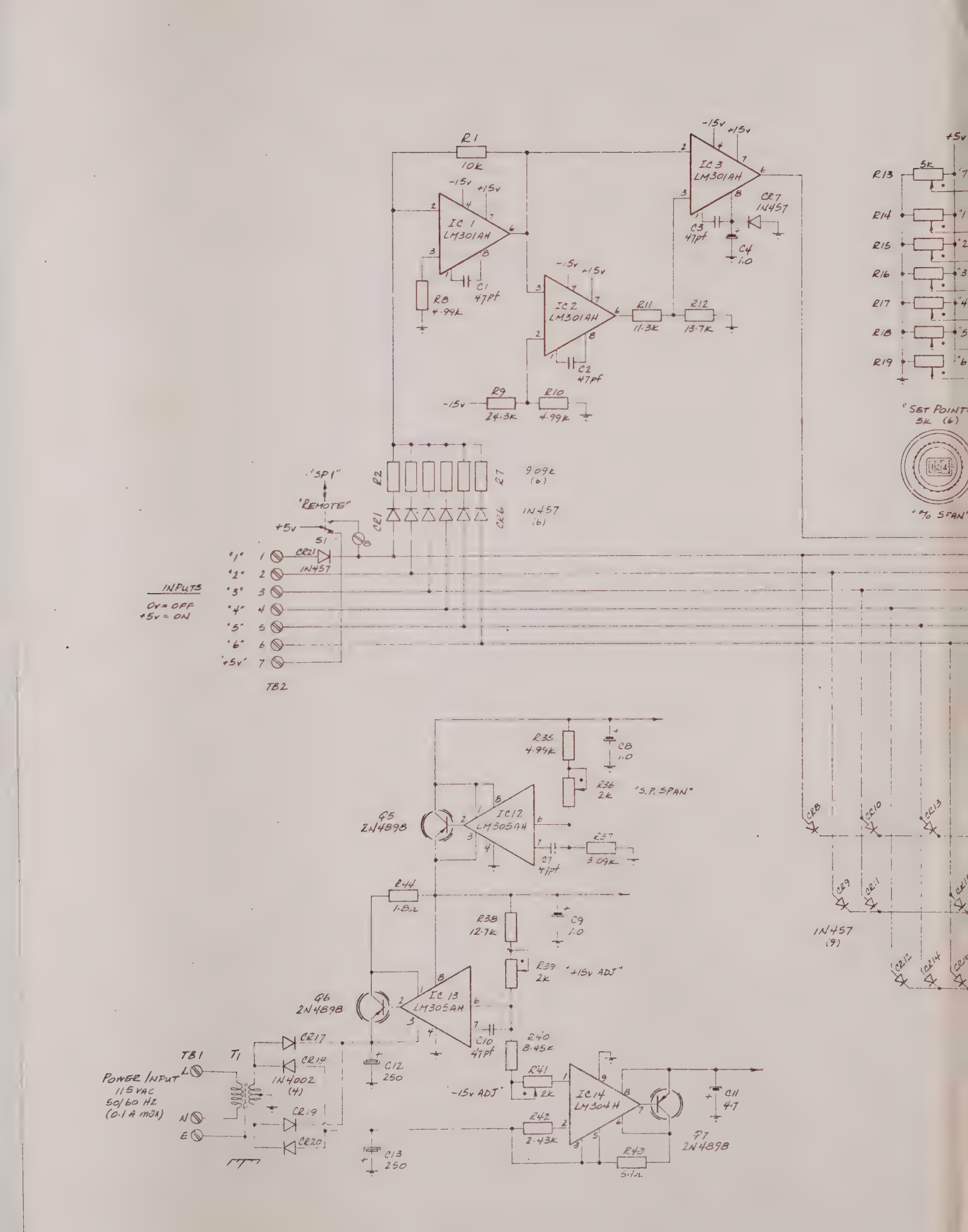
IED:
SUIT INSTALLATION)
BELDEN 8444 (4-CONDUCTOR)
- BELDEN 8442 (2 CONDUCTOR)
DEN 9430 (7-CONDUCTOR)
WITH 0/3007 & 0/3008
ONTROLLER TB3-7 & TB3-8
& TB3-2 (OBSERVE COLOR CODE).

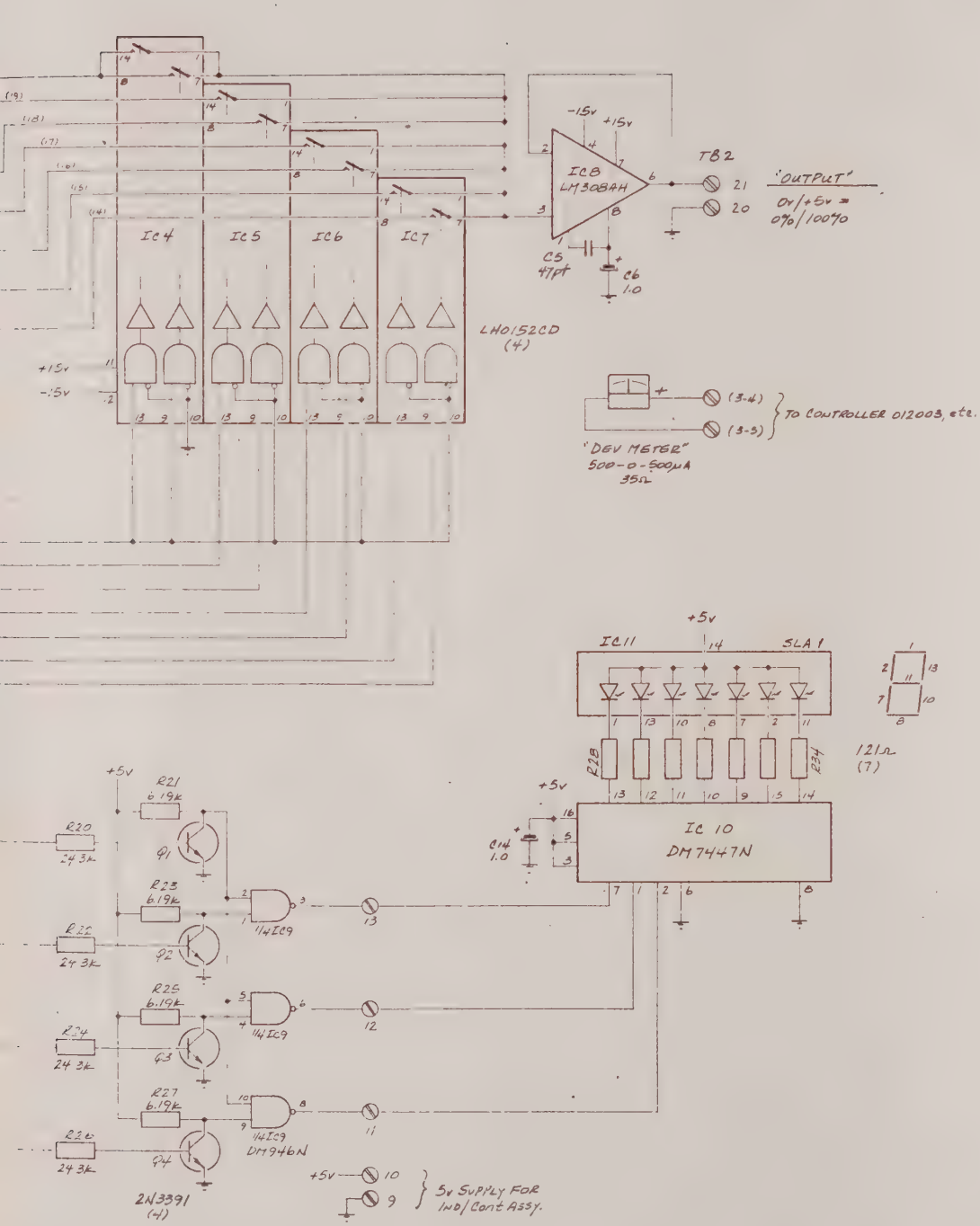
TYPICAL PROGRAMMED CONTROL SYSTEM
WIRING INFORMATION

REF: 0/2003

470271

REV #1: 16 APR 79 GW ADDED 1979 PGMR.


R1
10k
IC 1
LM301AH
IC 2
LM301AH
IC 3
LM301AH
-15v
+15v
R8
4.99k
C1
47pf
C2
47pf
C3
47pf
C4
1.0
CR7
1N457
R9
24.3k
R10
4.99k
R11
11.3k
R12
13.7k
+5v
R13
5k
R14
R15
R16
R17
R18
R19
"SET POINT"
5k (6)
"% SPAN"
"SP1"
"REMOTE"
S1
R2
R7
909k
(6)
CR1
CR6
1N457
(6)
INPUTS
0v = OFF
+5v = ON
"1"
"2"
"3"
"4"
"5"
"6"
"+5v"
CR21
1N457
TB2
R35
4.99k
C8
1.0
R36
2k
"S.P. SPAN"
Q5
2N4898
IC12
LM305AH
C7
47pf
R37
3.09k
R44
1.8k
R38
12.7k
C9
1.0
R39
2k
"+15v ADJ"
Q6
2N4898
IC 13
LM305AH
C10
47pf
R40
8.45k
R41
2k
-15v ADJ
R42
2.43k
R43
5.1k
IC14
LM304H
C11
4.7
Q7
2N4898
CR17
CR18
CR19
CR20
IN4002
(4)
C12
250
C13
250
TB1
T1
POWER INPUT
115 VAC
50/60 HZ
(0.1 A max)
L
N
E
CR8
CR10
CR13
CR9
CR11
CR12
CR14
CR15
1N457
(9)



SCHEMATIC DIAGRAM

SIX STATION SET POINT ASSEMBLY

REF: 013006 & 013007

470249

GARNER 25FE673

THERMOTRON CORPORATION HOLLAND, MICHIGAN U.S.A.

REV			
REV I	7/10/73	GA	ADD CKT

Slope Generator

27 November 1972

USER MANUAL

SLOPE GENERATOR

Assembly No. 013008, 013009

Dwgs: 470217
470224
470229
470233

TABLE OF CONTENTS

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X. Service

XI. Parts breakdown

XII. Model Variations

Introduction

The Slope Generator is essentially a Set Point transition rate controller.

The device is intended for use in applications which involve automatic control of some variable at one or more operating points. The purpose of the Slope Generator is to control the rate at which the variable moves towards the operating point (at start up, for instance) or to control the timing of a transition from one operating point to another.

Representative applications involve kilns, heat-treatment facilities, Reliability/Environmental Test Chambers, etc. The device can be scaled as necessary to adapt it to virtually any application.

The Slope Generator was first designed and manufactured by Thermotron to accommodate one of our own requirements related to the programming of temperature test chambers. By virtue of this background, the application which is currently most frequently encountered involves temperature transition rate control within an operating range of -125°F. to +375°F. Since this application is most common, it is referred to quite frequently in this manual, whenever an example is needed to help clarify the discussion. When the user's application is different, the points made in the text will still apply, even if the examples cited are not directly applicable.

Introduction (Continued)

The new Slope Generator system is functionally similar to its predecessor, Model 013001, but there any similarity ends. Model 013001, the original Slope Generator, was designed for a specific application, and was difficult to adapt to other applications. The new equipment is designed with application versatility in mind, and offers the user a greater range of flexibility, with a higher degree of precision. The new equipment is not directly interchangeable with Model 013001.

General Description

The purpose of the Slope Generator system is to control the transition rate of a process variable, either during start-up and shut-down operations, or during transitions from one set point to another.

In most applications, the Slope Generator intervenes between the set point system and the process controller. In such systems, a 0v/+5vdc signal is used to represent the process variable in terms of 0%/100% of span. For instance, in a temperature control system having a range of -125°F to +375°F, the 0v level is analogous to -125°F (0%) and the +5vdc level represents +375°F (100%).

The set point signals provided at the input of the Slope Generator must always have this 0v/5vdc relationship. Likewise, the output of the Slope Generator will always have this same relationship. The output may be attenuated, however, for compatibility with controllers which accept low-level set point signals. This can be accomplished with a simple resistor network, as explained in Section IV of this manual.

In operation, the Slope Generator acts like a slow "voltage follower" circuit. Whenever its input level changes, its output level will also change in the same direction, but at a slower rate. The output of the Slope Generator changes in a linear

General Description (Continued)

manner, at a rate which is preset during calibration or set by the operator by means of front panel controls. The output transition continues at this rate until the output is driven to the same value as the input. At this point, the transition ends and the output is held equal to the input, until the input is changed once again.

The set point information which is provided to the input of the Slope Generator may be derived from either a manual or programmed set point station. The input impedance of the Slope Generator is typically 70 Meg ohms, so the unit presents no significant load on the set point system. The general input requirements include (1) low electrical "noise", (2) accurate 0v/+5vdc calibration and (3) the input rate of change must exceed the rate of change which the Slope Generator is required to produce.

The output transition rate of the Slope Generator is adjustable over a range of zero to ±10,000 mv/minute. However, the output voltage range of the unit is limited to -.4vdc/+5.1vdc. The output is incremented or decremented at half-second intervals, such that it takes the form of a "staircase wave" rather than a purely linear ramp. In practice, transition rates as low as ±1mv/min. can be set with a reasonable degree of accuracy. Slower transitions are also possible, but require special calibration and involve a higher degree of uncertainty.

General Description (Continued)

The Slope Generator system has two major components. The basic Slope Generator Assembly 013008 contains a completely functional circuit system. The Slope Generator Indicator/Control Station provides an interface between the operator and the Slope Generator. The Indicator/Control Station includes an analog meter which can be set to measure or monitor either the input or the output of the Slope Generator. This unit also includes various mode switches, upscale and downscale digital rate adjustments, plus transition mode indicator lights. By means of the mode switches, it is possible to transfer the input directly to the output, thereby bypassing the Slope Generator. Where transition rate programming is used, these switches also allow operator intervention during programmed operation. In addition, "fast-set" and "stop and hold" functions can also be achieved.

In certain applications, operator capabilities may not be required, or desired. In these applications, the basic Slope Generator Assembly is used without its mating Indicator/Control Assembly. In such installations, the operating mode of the Slope Generator is established by means of "softwired" connections at its terminal blocks, and the unit is calibrated to provide preset upscale and downscale transition rates, as required by the application.

As mentioned above, the transiton rates may also be varied by a remote transition rate programmer. Programmed systems, also,

General Description (Continued)

may or may not include the Indicator/Control Station, depending upon the requirements of the application.

The basic Slope Generator Assembly is packaged as a simple "black-box" system component measuring approximately 12" x 6" x 2". This unit may be mounted at any convenient location, and preferably at a location which is relatively free of dust, vibration and temperature variation.

The Indicator/Control Station is a completely self-contained unit measuring approximately 10" x 5" x 2". This unit is designed for mounting on the operator's control panel and includes a three-foot cable for interconnecting it with the Slope Generator.

Specifications

Parameter	Min	Typ(1)	Max	Units
Input/Output Offset		±4.0	±15	mv
Hysteresis		±2.0	±7.5	mv
Roc Accuracy	±1.0	±0.7		%Roc
. . . plus	±5.0	±0.5		mv/min
Roc Stability	±5.0	±1.5		%Roc
. . . plus	±2.5	± .075		mv/min
Input Impedance	20	70		Meg Ω
Output Impedance			1.0	ohm
Output Loading			10.0	mA
Input Signal Range(3)	0		5.0	vdc
Output Voltage Limits(3)	-0.4		+5.1	vdc
Transition Rate Range(2)	0		±10,000	mv/min
Operating Temperature Range	0	25	55	°C
Power Requirements:				
Voltage:	100	115	130	vac
Frequency:	50		60	Hz

(1) Typical specs allow ambient temperature variations of ±5°C.

(2) See rated accuracy and stability for uncertainties affecting ultra-slow operation.

(3) Input and output are short circuit proof, but may be damaged if connected to potentials in excess of ±12 volts.

Installation and Wiring

New units should always be inspected, inside as well as outside, prior to installation. Look for evidence of abuse during shipping and handling, such as bent or broken parts, loose parts, broken wires, missing fasteners, etc.

Covers may be removed by pressing in gently at both ends to release the detents, then pulling the cover up and out of the tracks in the chassis.

Mounting information is provided in drawing 470229 for both the Slope Generator (013008) and the Slope Generator Indicator/ Control Station (013009).

The Slope Generator may be mounted in any position. However, the mounting method should provide for convenience during wiring, calibration and subsequent maintenance. Be sure to allow sufficient room for cover removal and access to terminal blocks and calibration adjustments.

The Slope Generator should be mounted in an area which is relatively free of electrical interference (noise) and vibration. Noise suppression for near-by motors, power contactors, etc., may be worthy of consideration.

To mount the Slope Generator, remove its cover and temporarily remove the circuit board assembly from the chassis (six screws). Then mount the chassis at the desired location, replace the

Installation and Wiring (Continued)

circuit board assembly and the cover.

NOTE

In mounting the chassis, use only #6 pan head or binding head screws. Inspect this installation carefully to assure that the heads of the mounting screws are at least 1/8-inch below the bottom surface of the circuit board, and cannot cause short circuits.

The Indicator/Control Station, if used, must be located within three feet of the Slope Generator, and should be located at some point which will be convenient to the equipment operator. This unit includes an analog meter, and should be mounted vertically with respect to the meter scale. Inclinations of up to 45 degrees are permissible, but in such cases the calibration of the meter should be verified prior to placing the equipment into operation. It is not normally necessary to remove the cover of this unit during installation, wiring or calibration, and rear access may not be required if the unit can be removed from its mounting location from its front side.

Wiring information for a "typical" process control application is provided in Drawing 470224. In this case, the Indicator/Control Station is used with the Slope Generator, and the application involves set point transition rate control for a temperature controller.

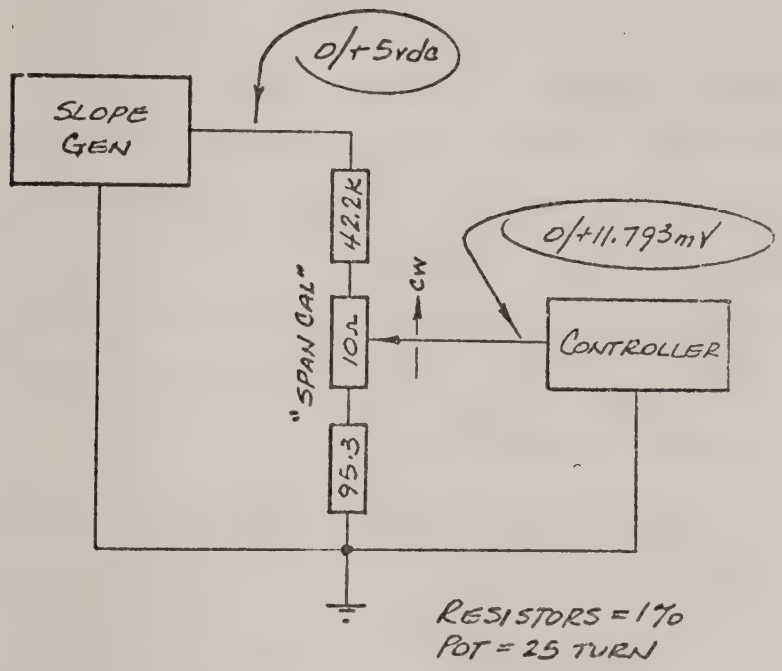
Installation and Wiring (Continued)

As shown in Drawing 470224, wiring involves connecting 115vac, 50/60 Hz power to TB1, input and output cabling at TB2, and connecting the Indicator/Control Station's cable at TB3 and TB4. The power line connected to the Slope Generator should be one which is relatively free of electrical transients.

The input signal is 0 - 5vdc, as is the output signal. Hence, the compatibility of the input source and the output load should be verified prior to making these connections. (See Specifications.) If it is necessary to attenuate the output of the Slope Generator to make it compatible with controllers or other loads which accept low level inputs, a simple voltage divider may suffice, and is easy to make using resistors. In general, the resistor values should be kept as low as possible in the interest of minimizing the possible effects of noise and loading, but the total series resistance presented to the output of the Slope Generator must not be less than 500Ω. If the attenuator is to be adjustable for the sake of precision, it should be recognized that the "wiper shift" for most trimpots is about equal to their resolution. Hence, the range of adjustment should be kept as small as absolutely possible so that shock and vibration will not destroy the calibration.

Temperature controllers which have a range of -125°F to +375°F, and which use a type T thermocouple, deal with input signals (from the sensor) which have a span of 11.793mv. Some

such controllers accept an identical set point signal, which is then compared directly against their input. A schematic diagram of an attenuator which would be suitable for this application is provided here as an example.



Whenever the Indicator/Control Station is used, the wiring will be as shown, regardless of the application.

When the application in question is not compatible with Drawing 470224, refer to Section XII of the User's Manual which was provided with the Slope Generator, for more specific information.

If this information is not available, it is possible to "work out" the wiring requirements for TB3 and TB4 by refering to the schematic diagram, Drawing 470217 ("wiring information" table). In some applications, the functions which are normally provided by the Indicator/Control Station may be permanently predetermined by using jumper wires at TB3 and TB4, and the potentiometers R18 and R22 may be located on the circuit board and preset for one specific output transition rate. In other applications, some but not all of the remote components may be used instead of the Indicator/Control Station. In every case, it is always necessary to provide for the functions of S1, S2, R18 and R22. The functions of S3, CR7 and CR9 may be treated as optional.

If desired, Thermotron Customer Service may be called upon for applications assistance and will be happy to provide specific wiring information for your particular application.

PRELIMINARY INFORMATION
(Subject to Change)

Operation

In applications where the Slope Generator is not equipped with its mating Indicator/Control Station, its operation is fully automatic. In such cases, the unit is specially wired and calibrated to provide a specified transition rate, and no operator intervention is required.

Where the Slope Generator Indicator/Control Station is used, the requirements imposed upon the operator consist only of selecting the desired mode of operation and adjusting the transition rates to the desired values. In order to accomplish this, operators should familiarize themselves with the function of each switch and adjustment on the control station. Towards this end, the following description is provided.

The Slope Generator Indicator/Control Station is equipped with the following:

1. An input/output indicator meter.
2. Upscale/downscale indicator lites.
3. Upscale/downscale transition rate adjustments.
4. A rate scale multiplier switch.
5. An indicator-output mode switch.
6. A manual-remote mode switch.

Operation (Continued)

The calibration of the meter is dependent upon the application. The -125°F to +375°F calibration is typical for temperature control systems. However, the scale may be calibrated in any system of engineering units which is significant for the application in question. In all other aspects, the Indicator/Control Station is the same in all applications.

The indicating meter provides a means of measuring or monitoring either the input or the output of the Slope Generator System, and is controlled by the indicator-output mode switch, S2. Since many systems of engineering units are non-linear, an analog meter is used. Since the meter scale can be graduated in a non-linear manner, a direct reading indicator can be provided for any system. In addition, the analog indicator provides a "relative" indication (i.e., indicates the input or output level with relation to 0% and 100%) which can be interpreted quickly at a glance.

The indicator-output mode switch has three positions, which are marked "NORMAL", "EinCK", and "BYPASS". In the normal position, the Slope Generator provides its normal transition rate control function and the meter indicates the output value. In the EinCK position, the meter is connected to the input of the Slope Generator without otherwise disturbing the normal function of the unit. This switch position allows the operator to check

Operation (Continued)

the input value whenever desired and is useful when pre-setting programmed input values. When the switch is moved to the Bypass position, the normal output of the Slope Generator is pre-empted and the input is connected directly to the output. In bypass operation, however, the Slope Generator continues to operate in the normal manner, even though it is not providing the output. Obviously, the meter indication provided during bypass operation is indicative of both the input and output value.

The upscale/downscale transition rate adjustment knobs are used in conjunction with the rate scale multiplier switch to establish the desired transition rate setting. The adjustment dials have a mechanical 3-digit read-out (000 to 999) and the scale switch has three positions which are labeled "X10", "X1", and "X.1".

The Slope Generator uses a 0v/+5v electrical analog to represent the programmed variable in a form which electrical circuitry can manipulate. For instance, in a typical temperature control system:

0v/+5vdc = -125°F/+375°F

This means that when the output is zero, a temperature of -125°F is called for, and if the output is +5vdc, a temperature of +375°F should result. Likewise, an output of +2.5vdc would be analogous to a temperature of about +125°F, if the temperature measuring system is linear.

Operation (Continued)

For any application, the analog can also be expressed in terms of "% of span":

0v/+5vdc = 0%/100% of span

For instance:

0v/+5vdc = 0%/100% = -125°F/+375°F

By the same token, the transition rate can also be expressed by any one of these conventions:

±volts/unit time

±% /unit time

±°F /unit time

By properly selecting the values of a few internal components, the Slope Generator can be configurated so that its digital transition rate dials are direct-reading in practically any system of engineering units.

Since the temperature programming application is the most frequently encountered, the following explanation is based upon that application. If the application in question is different, the pertinent system variations are summarized in the last section of this manual.

In temperature programming applications, the range of -125°F to +375°F is typically involved and the temperature transition rate is usually specified in terms of ±°F/minute average. The term "average" is used to account for the fact that the Slope Generator provides linear electrical transitions from one point to another on a temperature scale which may or may not be linear. If a thermocouple or RTD sensor is used in the temperature measuring system,

without linearization, then the actual temperature transition rate will vary, depending upon the operating points. This potential error affects both the actual instantaneous and average transition rates. Since linearization is expensive, "typical" systems are not so equipped, and methods of compensating for this limitation are given below.

For the typical temperature system, dual scaling of the transition rate controls is provided, as follows:

"mv/Minute" Scale		
Switch Position	Dial Position	Rate
X10mv	999+1	±10vdc/Minute
X1mv	999+1	±1vdc/Minute
X.1mv	999+1	±.1vdc/Minute

and:

"°F/Minute Ave" Scale		
Switch Position	Dial Position	Rate
X1°F	999+1	±1000°F/Minute
X.1°F	999+1	±100°F/Minute
X.01°F	999+1	±10°F/Minute

The "999+1" position of the digital dials represents their maximum clockwise position. The dials are continuously adjustable from "000" to 1000 ("999+1"), and the transition rate

varies accordingly, from zero to the maximums shown above. For instance, for a switch position of "X1mv/X.1°F and a dial setting of "100", the resulting transition rate will be ±100mv/min = ±10°F/min ave.

Note that this same transition rate would be produced by a switch position of "X.1mv/X.01°F" with a dial setting of "999+1". This would be the better choice of the two possible settings, since the transition rate dials are somewhat more accurate at the higher settings. Therefore, as a rule of thumb, always use the highest possible dial setting and the lowest possible multiplier (switch position).

Sensor Non-Linearity Correction

In order to produce accurate transition rates in terms of °F/min.ave. in non-linearized systems, proceed as follows:

1. Define T1 in % span on the basis of thermocouple millivolts (mv) or RTD ohms (R):

   RTD: % span at T1 = $\frac{RT1-R0\%}{R100\%-R0\%}$

   T/C: % span at T1 = $\frac{mvT1-mv0\%}{mv100\%-mv0\%}$

2. In a similar manner, define T2 in % span.

3. Find the difference in % span, between T1 and T2.

4. Multiply this number times ±5.0 volts in order to define the transition in terms of the 0v/+5vdc analog.

Operations (Continued)

5. Divide this number by the desired total transition time, in minutes, to find the correct setting in terms of "mv/min".

6. Set the multiplier switch and transiton rate dial(s) accordingly, in terms of "mv/min", ignoring the "°F/min" scaling.

7. By virtue of these settings, the Slope Generator will accurately execute a given transition in the "total transition time" specified in Step 5 above. Hence, the transition rate in terms of "°F/min ave" will be correct regardless of the position of T1 and T2 on the non-linear scale.

The above procedure should be used when (1) the temperature measuring system is non-linear and (2) precision transition rate accuracy is desired. In cases where the starting point (T1) and the end point (T2) lie on opposite sides of the 50% span point, good accuracy can result by setting "°F/min ave" directly; in other cases, the resulting accuracy may suffice if precision is not required. Naturally, if the measuring system is linear, precision accuracy will result from "°F/min" settings with no requirement for calculating corrective settings as per the above procedure.

Separate upscale and downscale transition rate adjustments are provided on the Indicator/Control Station. These may be set

independently, except that the scale multiplier switch applies to both dials simultaneously. A little arrow adjacent to either dial identifies which is which, plus the dials are color coded; orange being the upscale dial and green being the downscale dial.

Indicator lights associated with the rate dials (LED's) display the mode of the Slope Generator circuitry. When a transition is being executed, the light which is adjacent to the appropriate dial will flash ON and OFF at a one-second rate, which serves to indicate the direction and speed of the transition. When no transition is in progress, these lights remain OFF.

The "manual" - "remote" mode switch allows the operator to take command of the transition rate away from a remote transition rate programmer. If such a programmer is used in the system, a separate set of instructions are provided to cover its operation.

In the absence of a transition rate programmer, this switch can be wired to provide either one of the following functions:

(1) "fastset"

(2) "stop and hold"

Operations (Continued)

The "fast set" option is achieved by jumpering terminals on the back of the Indicator/Control Station:

connect 1 to 2

and 4 to 5

This function allows the Slope Generator to be driven rapidly to any setting by switching the manual/remote switch to "Remote" and the multiplier switch to "X10". The resulting rate will be ±10,000mv/minute, which will drive the Slope Generator over its entire range in 30 seconds.

Note that switching to "Remote" produces the same result as if both rate dials were set to "1000". As delivered from the factory, all Indicator/Control Stations will be wired in this manner.

The "stop and hold" option allows the operator to stop and hold the temperature setting at any point along a transition. This option is achieved by reconnecting the jumper wires on the back of the Indicator/Control Station:

connect 2 to 3

and 3 to 4

After this has been done, moving this switch to the "Remote" position will place the Slope Generator into a memory mode. In this mode, the Slope Generator circuit freezes its output and will hold that instantaneous value indefinitely, subject to drift, so long as this switch remains in the "Remote" position.

Operations (Continued)

In certain circumstances, this function can be quite useful. However, the output of the Slope Generator, in the memory mode, can drift upscale or downscale at a rate of up to ±30mv/hour. In the typical temperature application (-125°F to +375°F), this can amount to ±72°F/day.

Therefore, users availing themselves with this option should recognize that a potential safety hazard exists, especially when the application involves process control. The attendant safety hazard depends upon the nature of the application. In general, this switch should never be left in the "Remote" position (memory mode) for extended periods of time without operator supervision.

In order to help assure against inadvertent tripping, all three switches on the Indicator/Control Station are locking types. To change the switch position, it is first necessary to pull the toggle forward before it can be moved to a new position.

Simplified Circuit Analysis

When a capacitor is connected across the terminals of a battery, electrons will rush out of the negative terminal of the battery and into the capacitor. At the same time, electrons rush out of the opposite end of the capacitor and into the positive terminal of the battery. This happens because there is an excess of electrons at the (-) side of the battery and a deficiency of electrons at its (+) side; current resulting when the capacitor is connected is an attempt to resolve this imbalance.

Capacitors are constructed by separating two conductive elements (plates) with a very good insulator (dielectric), such that current is not able to flow through the unit. In the above experiment, current rushes into one side of the capacitor, and out the other side, only because charges seek equal distribution within the available "real estate". Once that excess electrons on the "negative"side and the deficiency of electrons on the "positive"side are equally distributed, then the current in the circuit is zero.

At this time, if the capacitor is disconnected and then connected across a voltmeter, one would find that it now carries a charge equal to that of the battery.

If its leads are now shorted together, the excess electrons on its negative side will rush thru the shorted leads to its positive side, where there was a deficiency of electrons. After

this happens, each atom in the conductive material will have been restored to equilibrium, each having its proper number of orbiting electrons, and a voltmeter measurement will indicate that there remains no charge when the short is removed.

The magnitude of the charge and discharge current in these experiments depends upon the size of the capacitor. If its plates are large, crowded electrons at the (-)side of the battery see wide open spaces to spread out into and a lot of them make a dash for it. Also, the (+) side of the battery is able to pull a lot of electrons out of the other side of the capacitor before they begin to be missed.

Capacitor sizes are expressed in farads. If a total charging current of 628 quadrillion electrons produces a charge of exactly one volt, then the capacitor is said to have a capacitance of one farad.

For convenience, 628 quadrillion electrons can be treated as a lot, and called one coulomb. It so happens that an ampere of current is defined as 628 quadrillion electrons, or one coulomb, passing a given point in a circuit in one second.

For another experiment, suppose that we connect one farad capacitor across a current source that puts out one ampere. A voltmeter connected across the capacitor would show that its charge increases at a rate of one volt per second. This is

the result of the fact that the current involved is one coulomb per second, and each coulomb produces a charge of one volt across the capacitor.

From this we can derive a formula which will permit us to calculate valves for any circuit such as this:

$$\Delta E_c = \frac{I}{C}$$

where:

ΔE_c = Voltage change across the capacitor in "volts per second"

I = Current, in "amperes"

C = Capacitance, in "farads"

By re-arranging this formula:

$$I = C \times \Delta E_c$$

and:

$$C = \frac{I}{\Delta E_c}$$

From the first formula, one can see that ΔE_c varies in direct proportion to I. In other words, if I is doubled, ΔE_c is doubled; if I is reduced by half, ΔE_c will be cut in half.

It is also apparent that the capacitor will charge and discharge at a constant, or linear, rate, since ΔE_c is simply expressed in volts per second.

As another experiment, suppose that we pour boiling hot water into a drinking glass which has been pre-chilled in a freezer. A broken glass results, by virtue of thermal shock.

Simplified Circuit Analysis (Continued)

The fractures are produced by high stress, which develops as the glass attempts to expand too rapidly, due to the sudden application of heat in large quantities. The stress develops because some parts of the glass are able to expand at a faster rate than others, due either to differences in mass or the uneven application of heat. Naturally, the glass would otherwise be able to withstand such temperature variations.

Now suppose we have the following problem. We must design a temperature test chamber for a certain electronic product. The product is to be tested by cycling the chamber temperature between -65°F and +160°F, holding at each temperature until the temperature of the product has completely restabilized. The temperature transition rate between the "soak levels" is to be at least ±9°F/minute on the average, and the product will be subjected to this cyclic exercise for several days. The electronic product, itself, contains thousands of parts, made of hundreds of different materials. Through careful design, the problems which could occur due to normal expansion and contraction with temperature, have been eliminated. However, we are less certain about the possible effects of fast temperature changes, since it is impossible to design this product such that all of its parts will restabilize to a new temperature at the same rate.

In view of this uncertainty, it would be unwise to exceed the stress level imposed by the ±9°F/minute specification.

Simplified Circuit Analysis (Continued)

If "tailor-made" to suit this specific test requirement, the test chamber can be designed so that its average temperature transition rate is about ±9°F/minute, with the product inside. This simplifies control requirements, since we can provide two set point adjustments for the temperature controller and simply switch from one to the other with a timer, permitting the chamber to "free run" between the -65°F and +160°F set points. The disadvantage is that if anything in this system changes, the transition rate calibration will be lost. In other words, this chamber might not be suitable for testing smaller products and would not be capable of testing larger products.

As an alternative, we could actually control the temperature transitions, such that they occur at a rate of ±9°F/minute, by programming the controller's set point on a continuous basis, instead of simply switching it between the two extremes.

Ideally, the programmer should be accurate, simple, and easy to program. This precludes the use of cam followers, curve followers, digital to analog converters, and the like.

Using what we know about capacitors, we can satisfy these requirements. First, we'll select a controller which accepts a voltage signal as its set point input. The unit selected has a range of -125°F to +375°F, and accepts a zero to +5vdc set point input.

Simplified Circuit Anaylsis (Continued)

Next, for the set point adjustment, we'll connect two potentiometers across a +5vdc power supply, so that their wiper voltage varies from 0v (-125°F) to +5v (+375°F) as they are turned in a clockwise direction. As a precision readout, these pots can be fitted with a digital counting dial which varies from "000" to "999" and can be interpreted as "% of span".

Then we can provide a capacitor, a bi-directional and adjustable constant current source, and a control circuit to control the direction of the constant current.

Finally, we'll connect the controller input across the capacitor, and the set point pots to the constant current control circuit through time clock contacts.

In operation, the time clock will connect one of the set points to the constant current control circuit. This circuit will control the direction of the current in such a manner that the capacitor is charged, or discharged, towards the set point voltage level. When the capacitor voltage and the set point voltage are equal, this circuit will turn OFF the constant current source. Since the controller sees the capacitor voltage as its set point signal, we can program the slope of temperature transitions by adjusting the constant current level. The programming task is then completed by adjusting the time clocks so that it switches the set point pots alternately in and out at the correct times.

Simplified Circuit Analysis (Continued)

In designing the "Slope Generator", we'll have to consider three factors:

$$\Delta E_c = \frac{I}{C}$$

Since the controller uses a 0v/+5v analog for its -125°F to +375°F temperature range, a ±10 millivolt change at its set point input is analogous to ±1°F. Since we want to produce a ±9°F/minute slope, ΔE_c will have to be about ±90mv/minute, or ±1.5mv/second.

This is a small ΔE_c. By inspecting the above formula, we can see that ΔE_c will be small when C is large and I is small.

For good accuracy, we can assume that the capacitor used will have to be a very good one. A review of various catalogues indicates that 10 microfarads is about the practical limit for ultra-high quality capacitors.

Having determined the values of ΔE_c and C, we can calculate the value of the constant current required:

$$\pm I = \pm \Delta E_c \times C$$
$$= \pm 1.5\text{mv} \times 10 \text{ ufd}$$
$$= \pm 15 \text{ nanoamperes}$$
$$(= \pm .000000015 \text{ amperes})$$

This is a very low level current. With practical, inexpensive components, it is not likely that we could build a current source which would be reliable at these low levels.

Simplified Circuit Analysis (Continued)

Going back to the formula, we originally assumed that I was continuous. On second look, if I is switched ON for only a fraction of each second, then ΔE_c will be proportionately reduced. If I is ON for only a thousandth of each second, then ΔE_c will be one thousandth of its normal value. On the other hand, for the same vlue of ΔE_c, switching I ON and OFF in this manner permits I to be 1000 times greater than its normal value. Hence, we can revise this formula somewhat:

$$\Delta E_c = \frac{It}{C}$$

where t = the length of time that I is ON during each second, in seconds.

Assuming that we'll permit the constant current to flow for only one millisecond per second, the constant current level becomes:

$$I = \frac{\Delta Ec \times C}{t}$$

$$= \frac{1.5mv \times 10mfc}{.001}$$

$$= 15 \text{ microamperes}$$

$$(= .000015 \text{ amperes})$$

This is a more practicable current value. Hence, to complete our set point programmer we'll add a chopper in series with the constant current, which permits current to flow during only one thousandth of each second.

A simplified block diagram of the Slope Generator is shown here. The circuit includes a clock which produces a reference

frequency of one cycle per second. Two adjustable constant current sources provide a positive current to charge the capacitor, or a negative current to discharge it, at an accurately calibrated rate. The upscale-downscale control circuit compares the input set point signal with the output signal, and operates the two switch circuits as necessary to drive the output towards the input. The control circuit also performs the "chopper" function which was discussed above.

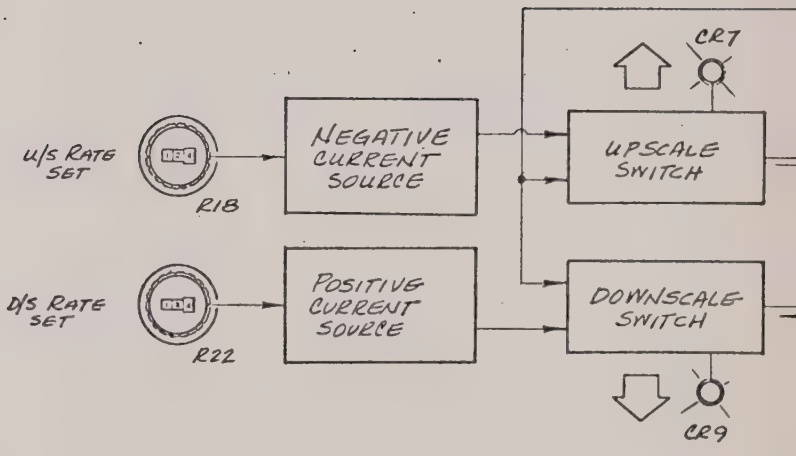
When the system includes an Indicator/Control Station, a switch is provided which allows the input signal to be connected directly to the controller, bypassing the Slope Generator. Another switch changes the chopper operation such that the constant current "ON" time is either 1ms, 10ms, or 100ms, which expands the range of the unit in three steps:

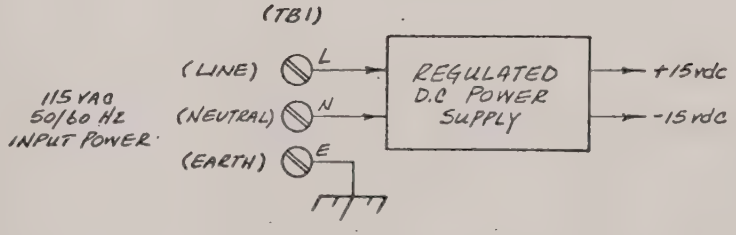
X.1 = 0 - 100 mv/min

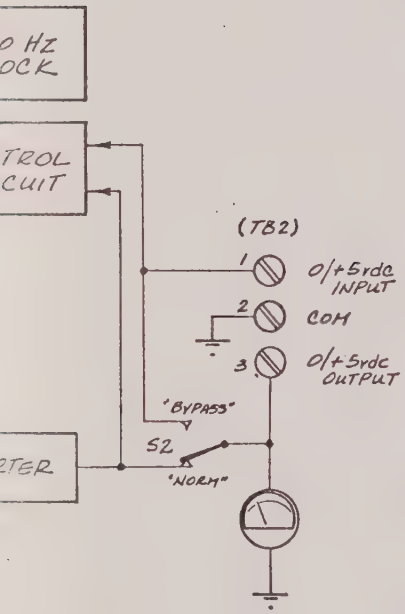
X1 = 0 - 1000mv/min

X10 = 0 - 10,000mv/min

This switch is used in conjunction with the constant current adjustments which are equipped with 3-digit 10-turn dials. An analog meter is also provided, by means of which the input set point signal or the output signal can be measured, or monitored. Finally, flashing LED indicators are provided, which indicate whether the output is being driven upscale, downscale, or if it is stabilized.


CR7
U/S RATE SET
R18
NEGATIVE CURRENT SOURCE
UPSCALE SWITCH
D/S RATE SET
R22
POSITIVE CURRENT SOURCE
DOWNSCALE SWITCH
CR9


(TB1)
115 VAC 50/60 Hz INPUT POWER
(LINE)
L
(NEUTRAL)
N
(EARTH)
E
REGULATED D.C POWER SUPPLY
+15vdc
-15vdc



OUTPUT R.O.C. IS ADJUSTABLE IN TERMS OF ±mV/Min USEING R18-R22 DIALS AND S1 SCALE MULTIPLIER SWITCH.

INDICATOR LITES CR7 & CR9 FIASH AT A RATE OF 1.0 Hz TO INDICATE UPSCALE OR DOWNSCALE OUTPUT TRANSITIONS.

DATE / BY / CHKD	TOLERANCE	DESCRIPTION	
	SCALE	SLOPE GENERATOR (TM) BLOCK DIAGRAM (SIMPLIFIED)	
	MATERIAL		
	FINISH	REF: 013008 & 013009	
	DRAWN BY GARNER	DATE 29Oct72	470233
	CHECKED BY	DATE	
	RELEASED BY	DATE	

As mentioned in the Introduction of this manual, the Slope Generator was originally designed by Thermotron to accom-modate some of our own temperature programming requirements. In fact, the above test chamber application is the one for which this equipment was designed. Since this has, by far, proven to be the typical application for the Slope Generator, it is used as a base for various discussions in this manual.

From the preceeding information in this section, however, it should be clear that the Slope Generator can be adapted to practically any process control application where transition rate control is required or desired. The input/output range of the equipment is simply 0v/+5vdc, and the transition rate range is ±0/±10,000mv per minute. Obviously, the 5vdc analog can be applied to any system of engineering units (temperature, pressure, motor speed, flow rate, vacuum, liquid level, humidity, etc.), and to any range. The equipment is also suited to applications other than process control (lighting control, special effects, test equipment, etc.). The only thing which "customizes" the Slope Generator for any particular application is the graphics used on the Indicator/Control Panel. A new meter scale and special legends can be printed as appropriate for any application, but otherwise the equipment is usually identical and the information presented in this manual remains valid for all users. (Any significant variations are noted in Section XII of the manuals delivered with the equipment.) In some cases, where neither adjustability or indication are required, the Slope Generator may be used without the Indicator/Control Station.

Simplified Circuit Analysis (Continued)

In the case of the -125°F to +375°F temperature application, the meter is calibrated with this temperature scale, using the curve of either a copper vs. constantan (Type T) thermocouple or a platinum resistance thermometer, depending upon which one of these electrical temperature sensors is used to provide the necessary temperature measurement for the controller. (Platinum RTD's are sometimes used where precision accuracy is required, otherwise thermocouples offer good accuracy, reliability, and interchangeability at much less cost.) Both of these scales have an equivalent °C calibration, and 10% markers. Both of these scales are non-linear, unless the system also includes a device which converts the non-linear response of the temperature sensor into a linear temperature measurement.

An electronic temperature controller actually controls electricity, not temperature. Such devices simply manipulate heat as necessary to set thermocouple millivolts or RTD ohms to a preset value.

At -125°F, the response of the thermocouple is about ±.017mv/°F. At +375°F, its response is about ±.030mv/°F. The total response of this sensor over this range is about 11.793mv, so its average response is about ±.024mv/°F.

This low level signal is multiplied by a factor of 425 within the controller, in order to boost if to the 0v/+5vdc analog level. Hence, the response at analog levels is about:

Simplified Circuit Analysis (Continued)

±7.225mv/°F near -125°F

±10mv/°F average

±12.750mv/°F near +375°F

Since the output of the Slope Generator varies at a linear rate in terms of mv/minute, it is obviously impossible to generate a linear slope in terms of °F/minute . . . unless a linearizing signal conditioner is added to the system between the thermocouple and the controller. Since this involves a cost of a few hundred dollars, it usually isn't done unless linear temperature transitions are mandatory.

In the absence of a linearizer, if we desired to perform transitions at a rate of ±1°F/minute, we could set the Slope Generator for a rate of ±10mv/minute, the average response of the temperature measuring system. The result, in terms of °F/minute, would be:

±1.43°F/min near -125°F

±1.0°F/min near 50% of span

±0.785°F/min near +375°F

This same discrepancy occurs when a platinum sensor is used, although to a lesser extent since the platinum element has a much more linear response. The fact is that in control applications the transition rate can be expressed in direct engineering units only if the measuring system is linear. Otherwise, it must be specified in average terms (e.g., ±°F/min ave) or in mv/min.

Simplified Circuit Analysis (Continued)

A method of setting the Slope Generator so as to provide precision transition times in conjunction with non-linear measuring systems is given in Section V of this manual.

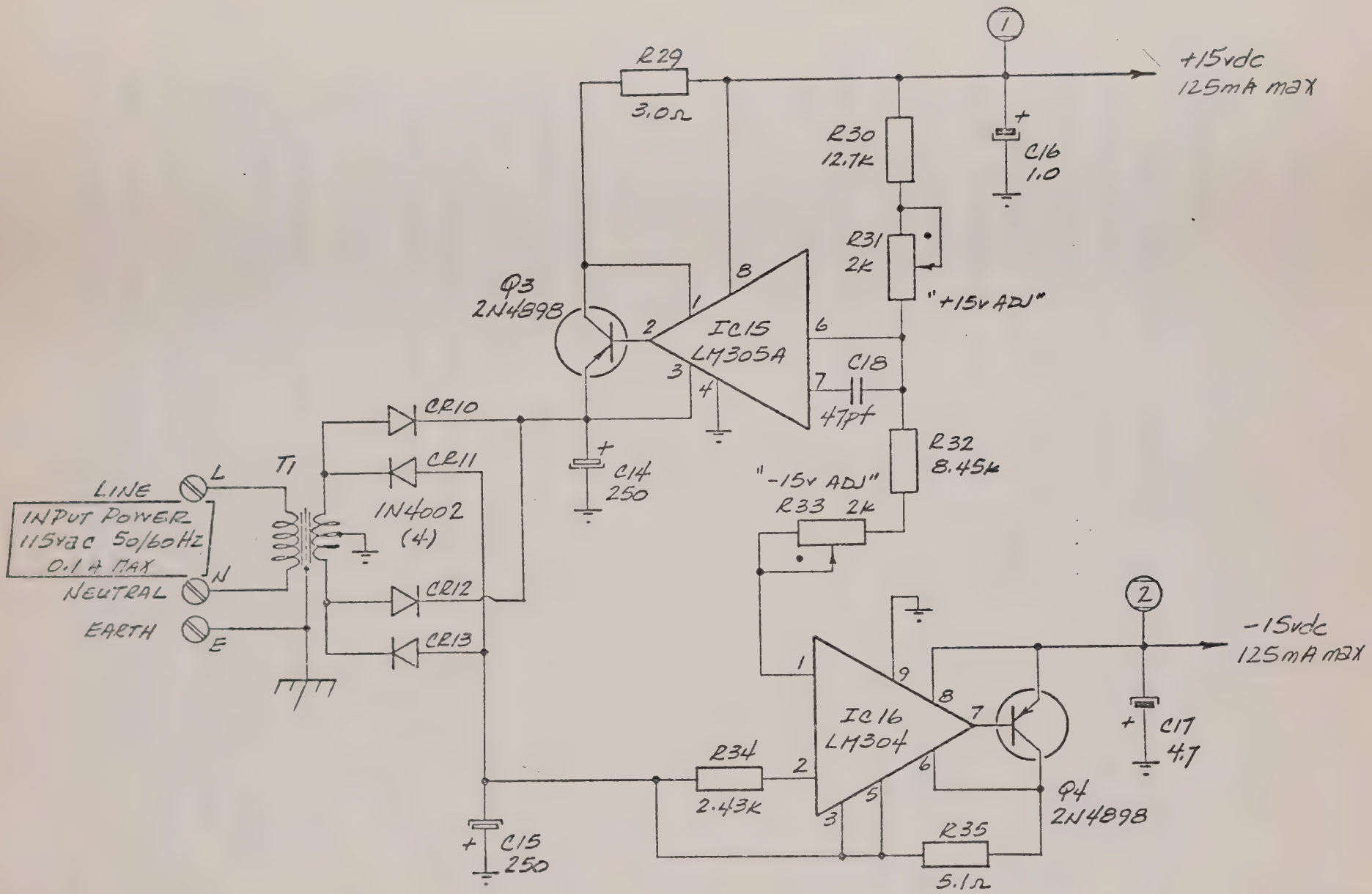
Careful readers may have observed that the output of the Slope Generator is not truly linear so far as time is concerned. The fact is that when it produces an upscale or downscale set point transition, it does so by incrementing or decrementing the output voltage in small steps. This is due to the operation of the constant current choppers which were discussed above. If we were to record the output on a wide-chart recorder, the result would be a line which is linear in terms of mv/minute, but which otherwise looks like a staircase. Circuits which produce this kind of output are frequently referred to "staircase-wave generators", for obvious reasons, and are frequently used in digital-to-analog (or visa versa) converters. The unique aspect of the Slope Generator is that it is probably the "slowest" staircase-wave generator of all, yet it still provides a reasonable degree of accuracy.

Since the choppers actually operate at a 2 Hz rate, the amplitude of each step is:

$$E_{step} = \frac{\text{Roc Setting in mv/min}}{120}$$

Hence, for a setting of 100 mv/min ($\triangleq$ 10°F/min), the amplitude of each step is about 0.833mv ($\triangleq$ 0.08°F), and two such steps occur during each second.

In process control applications, the slow response of the system being controlled will, as a rule, integrate these small steps in such a manner that they are completely "filtered out", and the end result is linear. In certain non-process, fast response applications, these steps might be a significant factor in evaluating the potential performance of the system.


R29
3.0Ω
+15vdc
125mA max
R30
12.7k
C16
1.0
R31
2k
"+15v ADJ"
Q3
2N4898
IC15
LM305A
C18
47pf
R32
8.45k
"-15v ADJ"
R33 2k
CR10
CR11
IN4002
(4)
CR12
CR13
C14
250
T1
LINE
INPUT POWER
115vac 50/60Hz
0.1A MAX
NEUTRAL
EARTH
L
N
E
IC16
LM304
R34
2.43k
C15
250
C17
4.7
Q4
2N4898
R35
5.1Ω
-15vdc
125mA max

Power Supply

This section of the handbook provides a detailed technical analysis of the Slope Generator circuitry. This analysis is provided for maintenance technicians, who will be responsible for maintaining the equipment in good working order and for correcting failures if and when they occur. This section is written with reference to the schematic diagram, drawing number 470217. That drawing should be referred to while studying this section of the manual. As a prerequisite to understanding the information presented in this section, the reader should first read sections I, II, III, V and VI.

(Insert Power Supply Diagram)

In any electronic device, a good power supply is essential to accurate, reliable operation. The Slope Generator circuit includes a bilateral 15 vdc power supply (+15vdc and -15vdc). Since these dc supply voltages are used to provide reference voltages, as well as power for the circuit, both are equipped with precision voltage regulators.

Transformer T1, diodes CR10 thru CR13, capacitors C14 and C15, form a bilateral, full-wave, unregulated dc power supply. These circuits convert the 115vac line power to ±30vdc levels, which appear at the top of C14 (+30vdc) and the top of C15 (-30vdc). These two dc levels are unregulated and will vary with the input line voltage, and the load current required by the circuit. Under

Functional Analysis (Continued)

Power Supply (Continued)

extreme conditions, they may vary by as much as ±10v, although during normal operation the variation will not usually exceed ±2 volts. It might be noticed that this circuit actually consists of two conventional full-wave supplies which share a common transformer. This transformer, T1, has a 3:1 step-down ratio and includes a "faraday shield" to prevent noise on the 115vac power line from being fed into the Slope Generator via capacitive coupling across the windings. This shield should always be connected to a good earth (waterpipe) ground.

IC15 and its associated components comprise the +15vdc regulator, while IC16 and its adjacent components form the -15vdc regulator. These two circuits operate on a semi-interdependant basis. Resistor R32 marks the dividing line between the two regulator circuits, and is a shared component.

The references for the two voltage regulators are included within the integrated circuits. IC16, an integrated negative voltage regulator, provides a precision constant current reference between its Pins 1 and 2. The magnitude of this current is fixed at about 1.0mA by R34. The path of this current is through R34, IC16, Pin 2 to Pin 1, R33, R32, R31 and R30. IC15, an integrated positive voltage regulator, includes a precision, temperature compensated constant voltage reference, the operating point of which is about +1.7vdc.

Functional Analysis (Continued)

Power Supply (Continued)

Pin 6 is the feedback terminal of IC15. In operation, IC15 will adjust the output voltage level as necessary to set Pin 6 at +1.7vdc, which balances this circuit with respect to its constant voltage reference. If R31 is set at 600Ω, then the voltage dropped across R30 and R31 in conjunction with the 1.0mA reference current will be 13.3vdc. Under these conditions, the output will be driven to +15vdc in order to set Pin 6 of IC15 at +1.7vdc.

The operation of the negative regulator, IC16, is somewhat different. In this case, the output is set by the value of resistance connected between Pin 1 of IC16 and ground. The scaling relationship is about 2vdc per kΩ. In other words, if a 7.5kΩ resistor was connected between Pin 1 and ground, the output voltage would be -15vdc.

Obviously, resistors R33 and R32 are not connected to ground, and it would appear that they would not meet the 7.5kΩ requirement even if they were. What is not obvious, however, is the fact that a virtual ground occurs within R32. Since the current through R32 is 1.0mA, the voltage drop across it is 8.45vdc. Since Pin 6 of IC15 is at +1.7vdc, then there must be a point within R32 where the voltage with respect to ground is zero volts. Measuring from this (inaccessible) point to the top of R32 would provide an indication of +1.7vdc. And from this point to the bottom of R32, the measurement would be -6.75 vdc. Hence, the effective resistance between this virtual ground and R33 must be about

Functional Analysis (Continued)

Power Supply (Continued)

6.75kΩ. Therefore, if R33 is adjusted to 750Ω, the total resistance from IC16, Pin 1, to the virtual ground will be 7.5kΩ, and the output of the negative regulator will be (2v/kΩ) -15vdc.

Both regulator circuits act by adjusting the load current so that the voltage drop across the load circuitry is 15 volts. In typical operation, the load currents are about ±45mA. Since the voltage across the regulators is about ±15 volts, the power dissipated by each of these circuits is (P=IE) about 675mW. Since this dissipation meets or exceeds the absolute maximum for the integrated circuits, booster transistors Q3 and Q4 are incorporated to handle the load current. This improves the regulation of each circuit by a factor which is about equal to the current gain of the booster transistors. In addition, handling the load outside of the IC's means that their temperature, and therefore, their reference circuits, will remain much more stable.

Both regulators are equipped with a current limiting feature which protects them, and to some extent the load circuitry, from overloads. The current limits are set at ±125mA by R29 (for the +15v supply) and R35 (for the -15v supply). In operation, the voltage drops across these resistors are monitored by their associated regulator circuits. The regulator circuits act as necessary to prevent these voltage drops from exceeding prescribed maximums (375mv for R29 and 635mv for R35).

Functional Analysis (Continued)

Power Supply (Continued)

Capacitor C18 is provided to compensate for the high frequency characteristics of IC15. IC16 includes its own internal compensation capacitor. These capacitors prevent high frequency oscillation within the integrated regulator circuits. Capacitors C16 and C17 are used to compensate for an interaction between the output circuitry of the IC's and the input of the booster transistor which can also produce high frequency oscillation. These capacitors also improve the transient response of the regulators. Since the instability is inclined to occur at high frequencies, low inductance (solid tantalum) capacitors must be used. Most other types have a high equivalent series resistance at high frequencies, and are not effective.

SHORT COURSE ON 'OP AMPS'

As can be seen on the schematic diagram, the linear circuitry consists mainly of operational amplifiers in I. C. form. It is a fact of life today that, no matter how much a designer would like to 'be original', a given function can usually be achieved more readily and more economically by using these prefabricated building blocks. The results, in terms of performance and reliability, will generally be equal or better than anything that can be achieved with an original design using discrete components. It is predicted that during this decade I. C. sales will triple, while the sales volume of discrete components will be reduced by half.

At the time of this writing we find ourselves nearing the middle of this trend, which started in the early 1960's.

Progress and change presents demands for continuing education. Unfortunately, since hindsight is always better than foresight, it is difficult to predict what knowledge will be required in the future, and one often finds that he has a lot of catching up to do in order to 'stay current.'

The following is provided as a ready reference for those who have fallen behind, and may provide some basic answers in a moment of need. Only the rudaments are covered however, and the maintenance technician would do well to expand his knowledge of these devices further by reading any one of several good books on the subject.

As indicated in the schematic diagrams, the op amp is treated as a single replaceable part of the circuit. What happens inside of this device? At the maintenance level, the details of its inner workings will not usually be required in order to judge whether or not the device is functioning properly. As a general rule, the integrated op amp can be treated as a 'black box' which

+ is an amplifier, a differential voltage amp
+ whose input impedance is infinite
+ whose output impedance is zero
+ whose open loop gain is infinite
+ whose power supply drain is insignificant

The pin connections shown on the schematic diagrams are, more or less, standard among all types of op amps.

As shown, these devices require bilateral power inputs (i. e., both a positive and a negative power supply). The negative supply is connected to pin 4, and the positive supply is connected to pin 7. In most applications the (+) and (–) power levels will be equal voltages, differing only in polarity. *Reversing the power connections to the device will usually result in its destruction.*

A small compensation capacitor is usually connected between pins 1 and 8 in order to stabilize the operation of the circuit. These devices are inherently excellent RF amplifiers, and in practical applications it is impossible to eliminate stray capacitances. Since the basic requirements for any self excited feedback oscillator are (1) an amplifier, (2) feedback in the proper phase and amplitude and (3) some sort of energy storage device to sustain oscillations and determine frequency, any practical op amp circuit is a potential oscillator. In the absence of the compensation capacitor these circuits will almost certainly oscillate at a frequency of 1 - 5 megahertz whenever their output is not at the positive or negative limit (saturation).

The op amp has two input terminals. Pin 2 is the *'inverting'* input, and pin 3 is the *'non-inverting'* input. Signals applied to pin 2 will be reproduced at the output with a greater amplitude and opposite phase. Signals applied to pin 3 will be reproduced as a magnified replica of the input (increased amplitude—same phase).

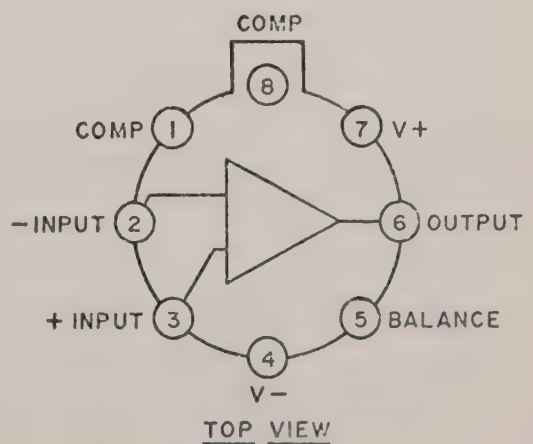
The output of the op amp is provided at pin 6. The output voltage can swing both positive and negative with respect to ground, and to within about 1.0 vdc of the supply potentials at saturation.

If the potentials at pin 2 and pin 3 are equal and of the same polarity, the output will be balanced at ϕvdc with respect to ground. In practical devices some small offset usually exists because of imperfections. This is known as the *'input offset voltage'* (the amount by which the inputs must be offset from perfect equality in order to bring the output to ϕvdc).

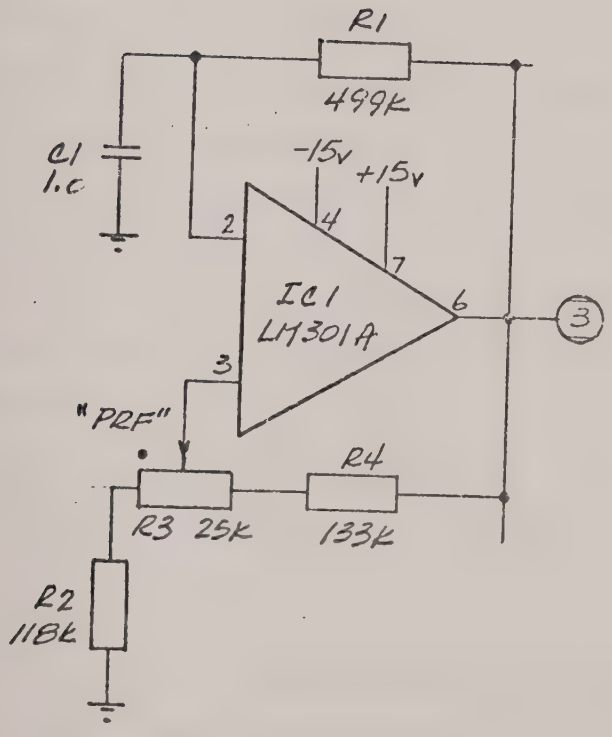
If the potential at pin 2 is greater (more positive) than that at pin 3, the output will be negative with respect to ground. Conversely, if the voltage at pin 3 is increased in the positive direction, the output will move in a positive direction.

How much the output changes for a given input variation depends on the gain of the circuit. Unless limited by the addition of external networks, the open loop large signal voltage gain may be as high as 300,000. This can be reduced to any lesser value by external feedback networks, while a non-inverting voltage follower (gain = 1) can be achieved simply by connecting pin 2 to pin 6, using pin 3 as the input.

These devices generally have integral overload protection at both their input and output terminals. This means that shorting these terminals to either supply or ground will not usually not harm the device. If, however, these terminals are shorted to a potential exceeding the supply levels (e. g., if the power supplies have been turned off) destruction of the device is likely.



TOP VIEW


R1
499k
C1
1.c
-15v
+15v
2
4
7
IC1
LM301A
6
3
3
"PRF"
R4
R3 25k
133k
R2
118k

1 Hz Multivibrator

- DIAGRAM HERE -

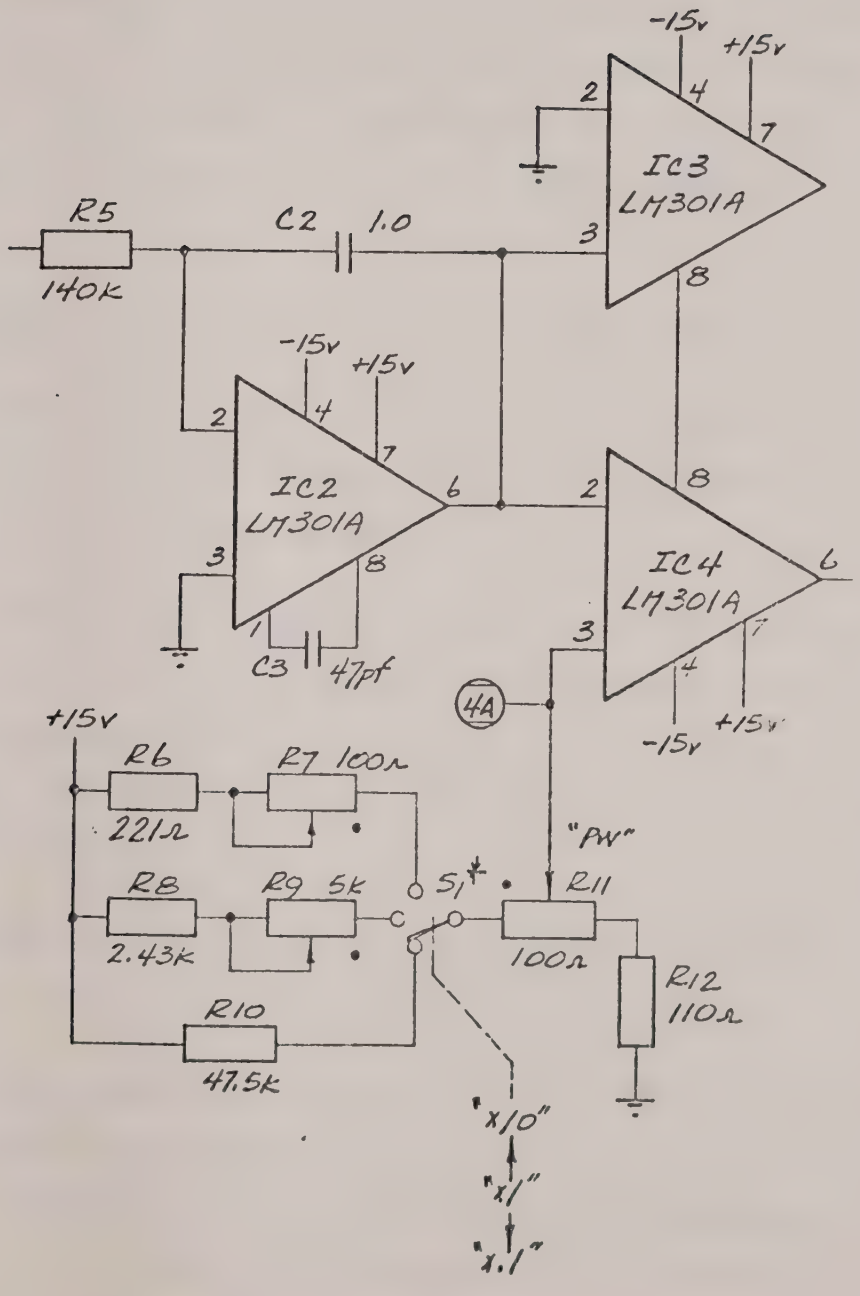
The "clock"circuit, IC1, provides a one cycle per second square wave, which is used as the time base of the Slope Generator.

Capacitor C1 and resistor R1 have an Rc time constant (T=RC) of about 500 milliseconds. In operation, IC1 switches alternately between its positive and negative saturation limits, which typically equal ±14.25 volts.

A reduced replica of this output square wave is developed by the adjustable voltage divider formed by R2, R3, and R4, and connected to the non-inverting input of the op amp. The potential connected to Pin 3 will be about +6.56v during the positive half cycle, and -6.56v during the negative half cycle.

When IC1 switches to the positive half cycle, C1 charges in a positive direction through R1. When the charge on C1 reaches +6.56v (the potential connected to Pin 3) the output of the IC will switch to its negative saturation limit, about -14.25 volts. At this instant, the potential across R1 is (-14.25v + 6.56v) about 20.81 volts.

C1 now begins to charge in the negative direction. In one time constant (.5 sec) C1 will charge through about 63% of the potential across R1, or through about 13.12 volts. Since the capacitor started its negative charge cycle from +6.56v, after .5 second it will have achieved a new level of (+6.56 - 13.12) -6.56 volts. During the negative half cycle, this same potential is present at Pin 3. Hence, when the charge on the capacitor reaches this level, the output of the IC will switch back to


-15v
+15v
IC3
LM301A
R5
140k
C2
1.0
IC2
LM301A
IC4
LM301A
C3
47pf
4A
+15v
R6
221Ω
R7 100Ω
R8
2.43k
R9 5k
S1
"PW"
R11
100Ω
R12
110Ω
R10
47.5k
"x10"
"x1"
"x.1"

1 Hz Multivibrator

+14.25 volts. In .5 second C1 will have returned to the +6.56v level, whereupon the output switches to -14.25v once again.

As is evident, this circuit will alternate between its positive and negative saturation limits continuously, producing a square wave output having an amplitude of about ±14 volts, and a frequency of 1.0 Hz, which may be precisely calibrated by means of R3.

Pulse Forming Circuits (DIAGRAM HERE)

The pulse forming circuits, IC2, 3 and 4, provide the accurately calibrated dc voltage pulses which are applied to the constant current choppers, Q1 and Q2.

The input to these circuits is provided by the clock circuit, IC1. The time required for IC1 to slew between its negative and positive saturation limits is about 150 microseconds. Hence, the 1 Hz square wave provided to the pulse forming circuit has sharp leading and trailing edges.

The purpose of IC2 is to soften these edges so that they will have a slope of ±100 volts per second.

The input square wave is applied to R5. Since op amps strive to balance their inputs (Pins 2 and 3), and since Pin 3 of IC2 is grounded, the output of IC2 (Pin 6) will vary as necessary to cause the entire input signal to be dropped across R5. Since the input square alternates between +14v and -14v, IC2 will produce currents of +.1mA and -.1mA in R5, in response to the input. Note that the level of this current is constant, and that it is bidirectional.

Pulse Forming Circuits (Continued)

Note also that capacitor C2 is in the current path.

When a capacitor is charged by a constant current, the charge rate, in volts per second, is:

$$\Delta E_c = \frac{I}{C}$$

By substituting values into this equation, it can be demonstrated that C2 will charge, bidirectionally, at a rate of 100volts/second.

Pin 2 of IC2 is a virtual ground, since its potential is (for all practical purposes) zero volts. Thus, when the clock signal at the input is +14 volts, current flows from Pin 6 of IC2 towards R5. This means that C2 (Pin 6) charges negative with respect to Pin 2. Hence, for a positive input, IC2 produces a negative-going output, and visa versa.

The output of IC2 takes the form of a "mesa wave". Since IC2 actually slews between its ±14v saturation limits at a rate of 100v/sec, the output during one cycle slews downscale during 280ms, rests downscale 220 ms, slews upscale during 280 ms and rests upscale 220 ms. C3 is the compensating capacitor for IC2, which controls the high frequency behavior of the circuit.

IC3 and IC4 are combined to form a double-ended limit detector, which in this case is used as a pulse forming circuit. The input to this circuit is the "mesa wave" generated by IC2, and is connected to IC3, Pin 3 and IC4, Pin 2.

Pulse Forming Circuits (Continued)

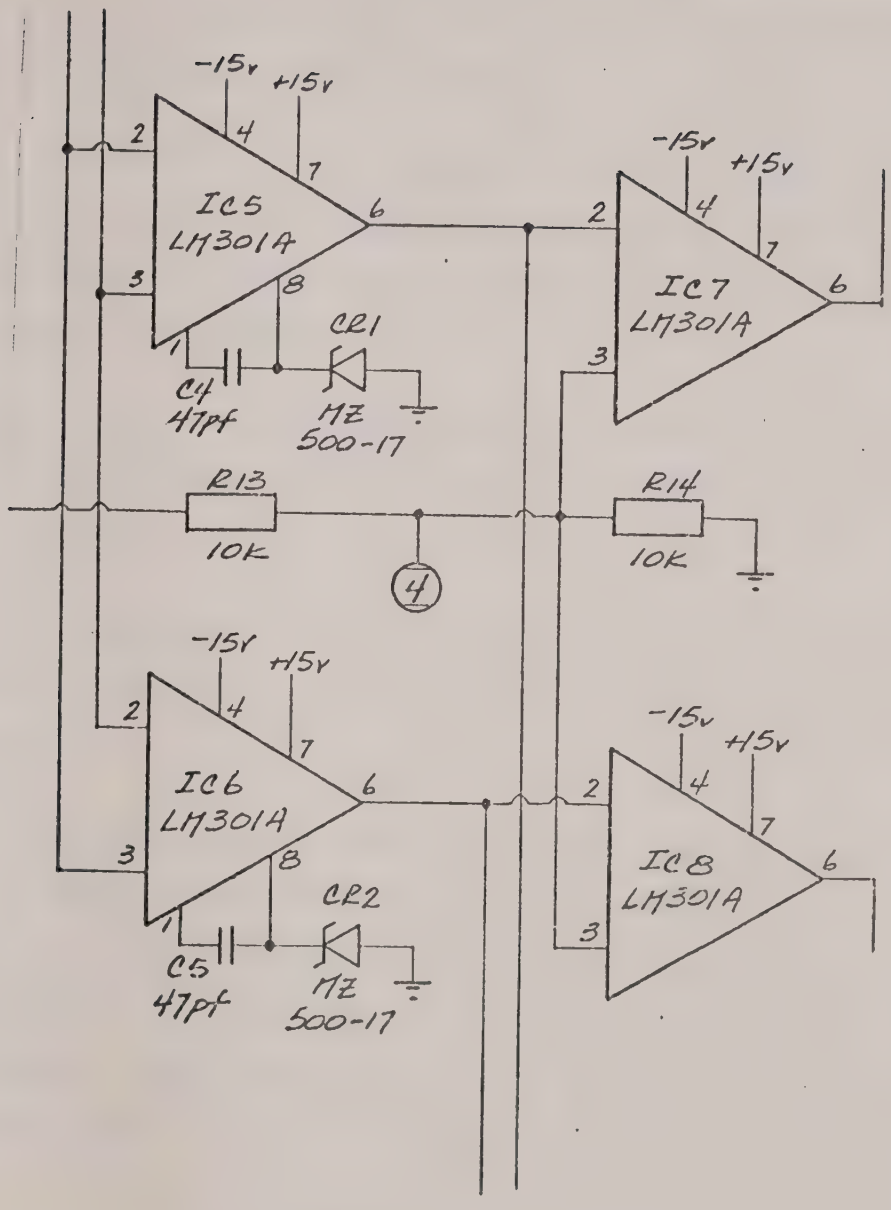
The operation of this circuit is controlled by two reference voltages, called the "lower trip point" (LTP) and the upper trip point (UTP). The LTP is zero volts, and is established by grounding the reference input of IC3, Pin 2. The UTP is variable. Deriving from the network consisting of R6 through R12, including S1, the UTP is connected to the reference input of IC4, Pin 3.

During operation, when the amplitude of the mesa wave is less than zero volts (negative), the output of IC3 will be at its negative saturation limit. During this same time, the output of IC4 would be at its positive saturation limit, except that by virtue of the common Pin 8 connections, the output of IC4 is clamped at the same level as the output of IC3, about -14 volts, and cannot move more positive.

When the amplitude of the mesa wave slews upscale, the output of IC3 switches to its positive saturation limit at the instant that mesa wave crosses the zero volt LTP. This removes the negative clamp, allowing the output of IC4 to swing to its positive limit.

Continuing to slew upscale, the mesa wave eventually crosses the positive UTP, at which instant the output of IC4 will switch to its negative limit.

This action produces a pulse at the output of IC4, Pin 6, whose width depends upon the slew rate of the input and the UTP setting.


-15v
+15v
IC5
LM301A
2
4
7
6
3
8
1
C4
47pf
CR1
MZ
500-17
IC7
LM301A
R13
10K
R14
10K
4
IC6
LM301A
C5
47pf
CR2
MZ
500-17
IC8
LM301A

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

A second pulse will be generated as the mesa wave slews back downscale, with IC4 being turned ON at the UTP, then clamped OFF as the mesa wave drops below the LTP.

Since the mesa wave slew rate is ±100v/sec, a 0.5ms pulse width could be achieved by setting the UTP at (.0005 x 100) +50mv. This is accomplished by switching S1 to the "x.1mv" positition and adjusting R11 as necessary.

Likewise, 5ms pulses can be produced by setting the UTP at 500 mv. This is accomplished by adjusting R9 while S1 is in the "x1mv" position.

Finally, 50ms pulses can be generated by setting the UTP at +5.0 volts. This is done with S1 in the "x10mv" position by adjusting R7.

As can be seen from the above, the pulse forming circuitry provides an output whose pulse recurrence frequency (PRF) is 2.0 pulses per second, and whose pulse width (PW) can be set for 0.5, 5.0, or 50ms, by means of S1. The PRF is established by the clock frequency. The significance of the above pulse widths will be presented below.

(DIAGRAM)

The comparator and gate circuits, IC5 through IC8, control the application of these precision pulses to the chopper transistors, Q1 and Q2.

Functional Analysis (Continued)

Pulse Forming Circuits (Continues)

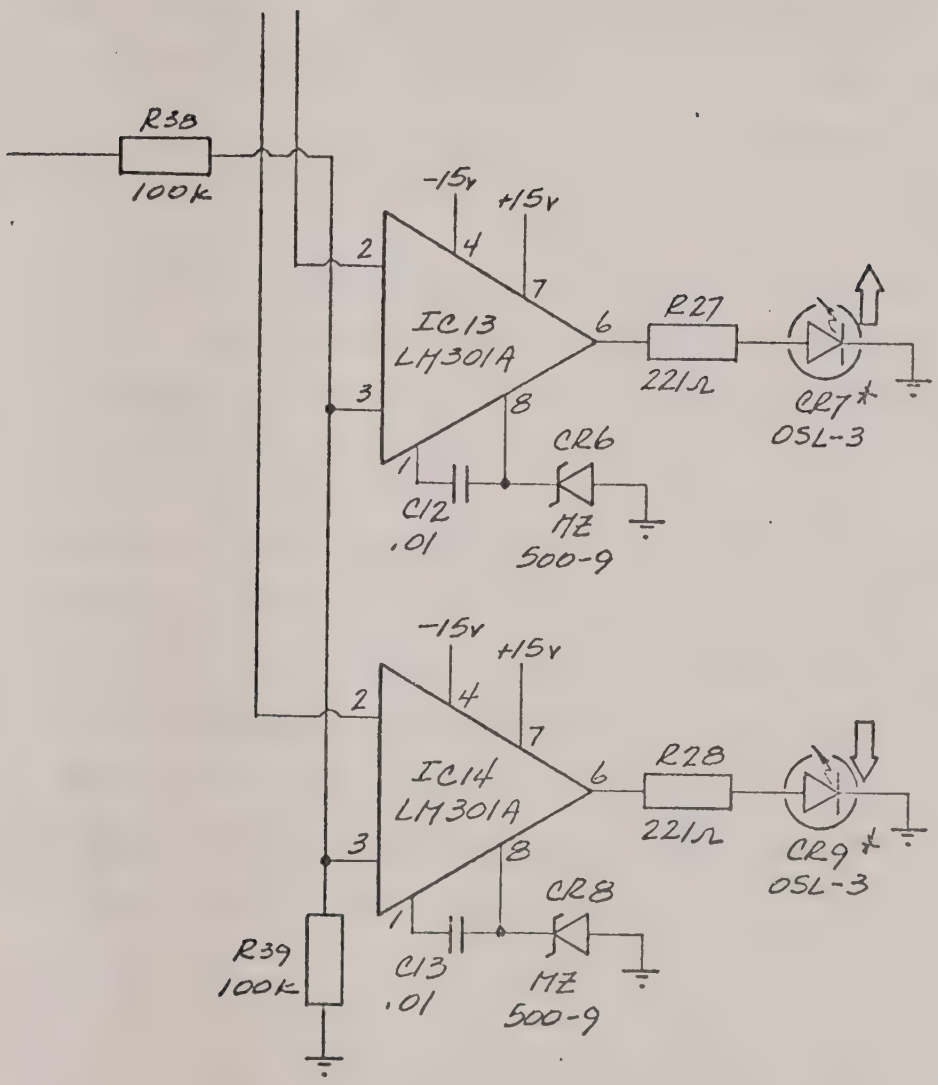
The precision pulses are fed to gate circuits IC7 and IC8, through a voltage divider composed of R13 and R14. Due to the voltage divider, the pulses provided at Pin 3 of IC7 and IC8 will have an OFF amplitude of about -7 volts and an ON amplitude of about +7 volts.

The inverting inputs of IC7 and IC8 (Pin 2) are controlled, respectively, by comparator circuits IC5 and IC6.

The comparator circuits compare the output set point voltage (from IC11 - 6) with the input set point signal (from IC17 - 6). At IC5, the ESP in signal (0-5vdc) is connected to Pin 2 and the ESP out signal is connected to Pin 3. When the output signal is less than the input signal, Pin 3 will be negative with respect to Pin 2, and the output of this circuit (Pin 6) will therefore be at its low limit. Due to clamping diode CR1, the "low limit" for this circuit is about -0.7 volts.

Hence, for this condition (output lower than input) Pin 2 of IC7 will be set at about -0.7 volt. Since Pin 3 of IC7 is pulsed by the ±7 volt timing signals, the output of IC7 (Pin 6) will swing between its saturation limits, ±14 volts. This output will have the same phase, pulse with, frequency and amplitude as the pulse signal produced at the output of IC4.

When the output signal is greater than the input signal, Pin 3 of IC5 will be positive with respect to Pin 2. The output


R38
100k
-15v
+15v
2
4
7
IC13
LM301A
6
R27
221Ω
CR7*
OSL-3
3
8
CR6
1
C12
.01
MZ
500-9
-15v
+15v
2
4
7
IC14
LM301A
6
R28
221Ω
CR9*
OSL-3
3
8
CR8
1
R39
100k
C13
.01
MZ
500-9

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

of IC5 will then be at its positive limit, which is set at about +11v by zener clamping diode, CR1. Pin 2 of IC7 will also be at this same potential. Since the pulse signal connected to Pin 3 of IC7 varies between ±7 volts, Pin 3 can never become positive with respect to Pin 2, and the output of IC7 will rest at its negative saturation limit, -14 volts.

In effect then, IC5 and IC7 act like a simple switch which connects the output pulses at Pin 6 of IC4 to the input of the upscale chopper, Q1, whenever the output set point signal is less than the input set point signal.

Comparator circuit IC6 and gate circuit IC8 are identical to IC5 and IC7, except that the inputs of IC6 are reversed with respect to IC5. This simply reverses the operation of these circuits. Specifically, IC6 and IC8 act like a simple switch which connects the output pulses at Pin 6 of IC4 to the input of the downscale chopper, Q2, whenever the output signal is higher than the input set point signal.

(DIAGRAM)

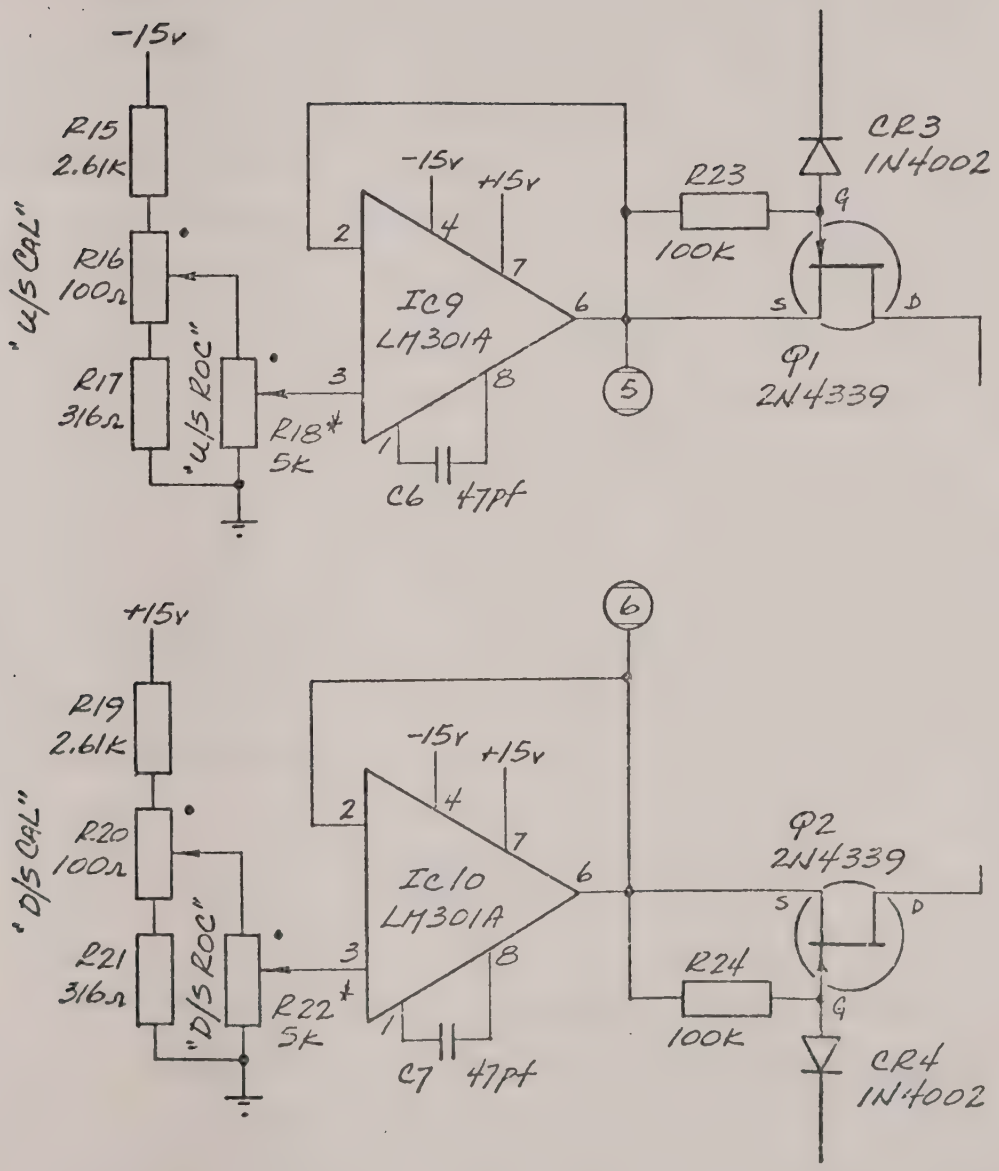
Pulse Forming Circuits (Continued)

The logical output signals of IC5 and IC6 are also used to operate the upscale and downscale indicator lights. As shown, these two outputs are connected to Pin 2 of the IC13 and IC14 (respectively), the indicator driver circuits. Pin 3 of both drivers is provided with a 1 Hz, ±7volt square wave from clock circuit IC1, through the voltage divider composed of R38 and R39.

When the slope generator is driving its output set point signal in the upscale direction, the output of IC5 will be at its -0.7 volt setting. Therefore, Pin 2 of IC13 will also be at -0.7 volt for this condition. The ±7 volts, 1 Hz signal applied to Pin 3 of IC13 will, therefore, cause the output Pin 6, to switch alternately between +5.1 volts and -0.7 volt, the clamped limits established by zener clamping diode CR6. When the output switches to +5.1 volts, a current of about 15 mA is drawn through the LED upscale indicator CR7 and R27. This causes CR7 to emit a visible quantity of light. When the output swings to its low limit, -0.7 volt, CR7 is reverse biased, and no current flows in the output circuit, so CR7 will be dark.

When the Slope Generator output is either stabilized or driving downscale, the output of IC5 will be about +12 volts. Since the 1 Hz signal at Pin 3 of IC13 is ±7 volts, Pin 3 of IC13 will always be negative with respect to Pin 2, and the output at Pin 6 will remain at -0.7 volt. Hence, CR7 will remain OFF.

The downscale driver and indicator circuit, which involves IC14 and CR9, is identical to the upscale circuit, except that its controlling input is provided from the downscale comparator IC6.


-15v
R15
2.61K
R16
100Ω
R17
316Ω
"4/5 CAL"
"4/5 ROC"
R18*
5K
C6 47pf
IC9
LM301A
-15v
+15v
2
4
7
6
3
8
1
5
R23
100K
CR3
IN4002
Q1
2N4339
S
D
G
+15v
R19
2.61K
R20
100Ω
R21
316Ω
"D/5 CAL"
"D/5 ROC"
R22*
5K
C7 47pf
IC10
LM301A
6
Q2
2N4339
R24
100K
CR4
IN4002

Pulse Forming Circuits (Continued)

As has been shown, the upscale/downscale indicators operate only during periods when the Slope Generator is actually in the "slope" mode, and these lights flash ON and OFF at a rate of one cycle per second. CR7 and CR9 are a part of the Slope Generator Indicator/Control Station (013009). Where this item is not included in the system, similar LED's may be connected for remote indication, or for test purposes. These outputs will not provide sufficient power to drive incandescent lamps. Capacitors C4, C5, C12 and C13 are compensation capacitors which control the high frequency characteristics of their respective op amp. C12 and C13 are sized so as to "soften" the turn ON and turn OFF of IC13 and IC14, which handle relatively large output currents. This helps to prevent these circuits from generating bursts of high frequency noise during switching operation. Resistors R27 and R28 establish the current through CR7 and CR8, at about 15 mA, which assures optimum LED brightness and long life.

(Diagram here)

IC9 and IC10 are precision voltage reference circuits. IC9 provides a negative reference voltage which is adjustable over the range of 0v to -1.666v by means of R18. IC10 provides a complimentary positive reference voltage, which is adjustable over the range of 0v to +1.666v by means of R22.

Pulse Forming Circuits (Continued)

R18 and R22, the "Slope Rate" adjustments, are normally a part of the Slope Generator Indicator/Control Station (013009), and are equipped with precision three-digit numerical read-out dials. Where the 013009 Indicator/Control Station is not used, R18 and R22 are 25-turn trimming potentiometers mounted on the Slope Generator circuit board.

IC9 and IC10 are wired as voltage followers. These circuits prevent any significant loading of the reference voltage dividers composed of R15 thru R18 and R19 thru R22. The voltage followers require very little input current and are able to provide large amounts of output current, although this latter capability is not significant in this case. In operation, IC9 and IC10 will act as necessary to balance their inputs, Pins 2 and 3. From inspection of the circuit, since the output (Pin 6) is connected directly to the inverting input (Pin 2), it is obvious that the output of these circuits will always be the same as their input, which is 0v to 1.666 volts, and is applied to Pin 3. The gain of these circuits is therefore equal to 1.0, and for this reason they are sometimes called non-inverting unity gain buffer circuits. C6 and C7 are the compensation capacitors for these buffers.

Trimming potentiometers R16 and R20 are used to set the outputs of IC9 and IC10 at exactly -1.666v and +1.666v, respectively, when R18 and R22 have been set to "1000" (or fully clockwise).

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

Transistors Q1 and Q2 are the upscale and downscale choppers. These are field effect transistors, or "N-channel JFET's". Their gate, source and drain terminals are identified on the schematic diagram. The voltage which is applied to the gate terminal of the JFET is used to control the resistance between its source and drain terminals. When the gate terminal is more negative than -1.8 volts, with respect to the source terminal, the resistance between the source and drain is essentially infinite. Conversely, when the gate-source voltage difference is zero, the source-drain resistance is less than 1000 ohms.

From the previous explanation of the gate circuits IC7 and IC8, recall that the output of IC7 will be -14 volts, except when the output set point signal is lower than the input set point signal, in which case a series of pulses will be sent to CR3. These pulses will have a PW of 0.5, 5.0 or 50mS, a PRF of 2 PPS and will achieve a peak amplitude of +14 volts. They ride a -14 volt reference.

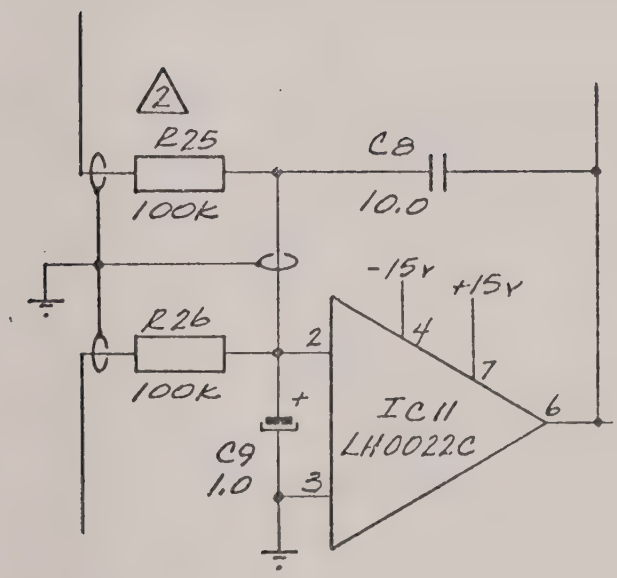
When the input to CR3 is -14 volts, either between pulses or in the absence of pulses from IC7, CR3 will be forward biased. Current will flow from IC7-6, thru CR3, thru R23 and into IC9-6. Pin 6 of IC9 can never be more negative than -1.666 volts, which assures that CR3 will always be forward biased when IC7-6 is at -14 volts. The maximum voltage drop at CR3 is about 0.7 volt. Hence, the gate of Q1 will be at a potential of about -13.3 volts during this condition, and the source-drain resistance will be essentially infinite (greater than 15,000 Megohms).

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

When the Slope Generator is in an "upscale" mode, the positive pulse train will be presented to CR3. Since these pulses may achieve an amplitude of +14 volts, each such pulse will reverse bias CR3, and no current will flow through the diode for the duration of the pulse. During this time, the gate voltage of Q1 will be the same as its source voltage, since it is connected to Pin 6 of IC9 through R23, and since there is no current thru, and so no voltage drop across, R23. Since the gate-source voltage difference at the JFET is zero, its source-drain resistance will be less than 1000 ohms. This low resistance then permits the output of IC9, the 0v to -1.666v reference voltage to be felt at R25. After the positive pulse has passed, the gate will once again be at the -13.3 volt potential and the JFET will revert to its blocking state.

To summarize, the JFET Q1 acts like a switch which is controlled by the precision timing pulses, which are gated through IC7 whenever the Slope Generator is in an upscale mode. This chopper, or "switch", connects the negative reference voltage provided from IC7-6, to R25 during its short ON intervals. The result is that the input to R25, during the upscale mode, will be a series of pulses having a PRF of 2pps, a PW of 0.5, 5.0 or 50mS (depending upon S1) and whose amplitude is set by the "Slope Rate" adjustment R18 over the range of 0v to -1.666 volts.


2
R25
100K
C8
10.0
-15V
+15V
R26
100K
2
4
7
6
IC11
LH0022C
C9
1.0
3

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

The operation of the downscale chopper, Q2, is the same as that of Q1, except that it operates only while the Slope Generator is in the downscale mode, and passes pulses having an amplitude of 0v to +1.666v, as set by the downscale "Slope Rate" adjustment R22. A detailed evaluation of this circuit is left as an exercise for the reader.

(Diagram)

IC11 and its associated components form the slope generating circuit. It can be seen by casual inspection that, except for component values, this circuit is essentially the same as the "mesa" wave generator circuit, IC2.

The input to the slope generator circuit is derived from either Q1 or Q2. Note that this is an "either, or" situation; inputs are never provided simultaneously from both of these sources. Furthermore, at times when the output set point signal is equal to the input set point signal, there will be no input to IC11 from either source.

So far as the two possible inputs are concerned, it is important to realize that they will always be identical, except in terms of amplitude and polarity. Recapping: the input, when present, is always a pulse train whose PRF is 2 pps, and whose PW is:

S1 Position	PW
X.1	0.5ms
X1	5.0ms
X10	50ms

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

If the input pulses are provided from the upscale chopper, Q1, their polarity is negative. Conversely, input pulses supplied by Q2, the downscale chopper, are of positive polarity. Finally, the amplitude of the pulses will be within the range of 0v to 1.666 volts, with the upscale and downscale systems being independently variable by means of the separate "slope rate" adjustments, R18 and R22.

In analyzing this circuit, the following case will be used:

Input Source: Q1 (upscale chopper)

Pulse Amplitude: -1.666 volts

Pulse Width: 0.5ms

This input is applied to R25. During the 0.5ms on time of Q1, IC11 produces a current of 16.66 uA thru R25 into one side of C8, and from the opposite side of C8 to its output, Pin 6. By virtue of this current, the voltage drop across R25 will be (E=IR) 1.666 volts. This leaves Pin 2 of IC11 at 0 volts (virtual ground) and thereby satisfied its "balanced inputs" requirement.

During this same interval, C8 is experiencing a constant current, 16.66 uA. From our evaluation of the IC2 circuit, recall that when subject to a constant current, a capacitor charges at a linear rate:

$$\Delta E_c = \frac{I}{C}$$

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

For this case, then, C8 charges at a rate of (16.66uA - 10ufd =) 16.66v/sec. However, each input pulse lasts for only 0.0005 second, so ΔE_c for each pulse is only 0.833 mv.

Since two pulses occur per second, ΔE_c is 1.666 mv/sec. Since one minute includes 60 seconds, ΔE_c is 100mv/min. (error due to rounding).

Since the direction of the current involved at C8 is towards Pin 6 of IC11, the charge across the capacitor, as measured between Pin 6 and ground (or the virtual ground, Pin 2), will grow increasingly more pisitive. Since the voltage at Pin 6 of IC11 is the unbuffered output set point signal, it is evident that this signal is being driven upscale towards its maximum +5 volt (100%) potential.

When the upscale chopper, Q1, switches to its OFF state, which lasts for 499.5ms between consecutive input pulses, the "input" to R25 is zero. Since this, in itself, satisfies the "balanced inputs" requirement which IC11 acts to maintain at all times, there will be no current flow through R25, C8 or the output of IC11, Pin 6. Since $\Delta E_c = I \div C$, and since I = zero, it is evident that ΔE_c = zero. This means that the charge on C8 and, therefore, the output voltage at Pin 6 of IC11, do not change this interval. The output signal will, therefore, rest at whatever value it had achieved by the end of the last, most previous, input pulse.

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

The downscale input is provided through the downscale chopper, Q2, and is applied to R26. Operation in the downscale mode is just the same as in the upscale mode, except that the polarity of the downscale input pulses is positive. This means that the direction of the current which flows in the R26, C8, Pin 6 circuit is reversed, and flows from Pin 6, thru C8 and R26, to Q2. This means that the capacitor charges in the opposite direction (or discharges) and, hence, the output set point signal will be driven downscale towards its minimum Ovolt (0%) level.

When the input pulses have an amplitude of 1.666 volts and a pulse width of 0.5ms, these parameters result from a "slope rate" setting of "1000" (or fully clockwise) and a multiplier switch (S1) setting of x.1mv/min. Hence, the Slope generator had been set to produce a transition rate of (1000 x.1mv/min) 100mv/minute, and, as was demonstrated above, this was achieved. By switching the scale multiplier switch, S1, to the X1 or X10 position, the output transiton rate would be changed to 1000mv/min, or 10,000mv/min, respectively. This follows, since in the X1 position, the pulse width becomes 5.0ms, and in the X10 position, 50ms (10 or 100 times longer, respectively).

As was seen above, the Slope Generator's output signal is incremented and decremented in a series of small steps. For the above case, the output changed ±833uV per step. Hence, the output signal takes the form of a "staircase" wave, ascending or descending.

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

It is important to emphasize three points. First, IC11 always does whatever is necessary to hold Pin 2 at the same potential as Pin 3 (i.e., ground potential). Second, both inputs are never ON at the same time. Third, the resistance from Pin 2 to the source terminal of an OFF chopper is so high (over 15,000 meg ohms), that for all practical purposes an "open circuit" exists along that path.

Naturally, the components used in the Slope Generator circuit are not perfect, although they approximate "ideals". The chopper JFETs manifest a small amount of drain-source leakage in the OFF state. Likewise, capacitor C8 is subject to a small amount of leakage. IC11's inputs also pass a small amount of current. As indicated in the specifications, the combined effect of these imperfections, when added to the possible errors affecting the PRF, PW and amplitude of the input pulses, might produce transition rate errors of "±1% ROC plus ±5mv/min" at the worst, but typically within "±7% ROC plus ±.075mv/min". In other words, it should be possible to bring the transition rate accuracy within these limits, using the calibration procedures provided in this manual. When this is not possible, a defect in the circuit is indicated.

When a defect is suspected, first check the input pulses for PRF, PW and amplitude by connecting an oscilloscope to the drain terminals of Q1 and Q2. An OFF condition drain voltage of more than ±5uv indicates excessive FET leakage. Trace any other input discrepancy back towards the circuitry which is responsible for

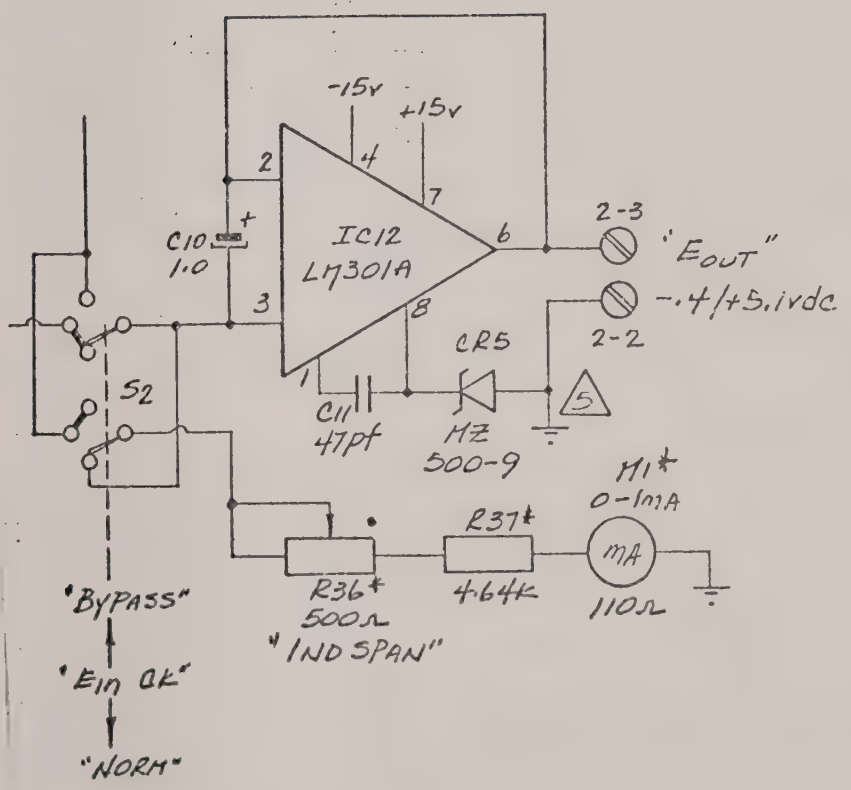
Functional Analysis (Continued)

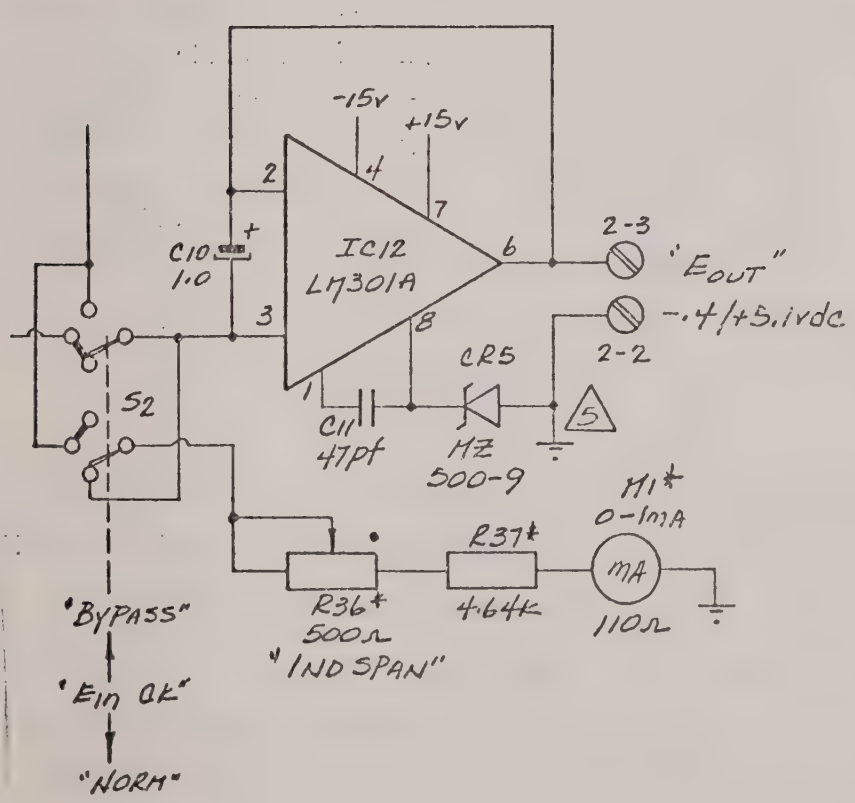
Pulse Forming Circuits (Continued)

the parameter in question. If the inputs are correct, slew the output to +5volts, then turn both slope rate adjustments (R18 and R22) fully counterclockwise. All test equipment must be disconnected from the circuitry at this time. If the output gradually diminishes, probabilities favor capacitor leakage (C8). However, this could also indicate excessive input bias current at Pin 2 of IC11. To establish which, short Pin 2 to ground; if the drift persists, the cause is C8. If the drift diminishes significantly, or if the output drifted upscale prior to grounding Pin 2, IC11 is probably at fault.

In general, any measurements made at Pin 2 of IC11 will provide ambiguous and unreliable indications, since this part of the circuitry is quite vulnerable. Also, contamination of this area of the printed circuit board can produce indications which appear to be faulty components, due to leakage currents across the board. If the board is not clean, clean it with chlorthene or a freon cleaning agent, being careful to remove any and all films and residues prior to any further troubleshooting.

Finally, capacitor C9 is used to prevent the input FET's within IC11 from being forward biased by transient noise signals. This capacitor, effectively, shunts such signals to ground. In the absence of C9, noise signals can cause the output of IC11 to "step" erratically to values which are grossly in error (usually in the downscale direction).


-15v
+15v
4
7
2
IC12
LM301A
6
3
8
1
C10
1.0
C11
47pf
CR5
MZ
500-9
2-3
"EOUT"
-.4/+5.1vdc.
2-2
5
S2
"BYPASS"
"EIN OK"
"NORM"
R36*
500Ω
"IND SPAN"
R37*
4.64k
M1*
0-1mA
mA
110Ω


-15v
+15v
IC12
LM301A
2
4
7
6
3
8
1
C10
1.0
C11
47pf
CR5
HZ
500-9
2-3
"EOUT"
-.4/+5.1vdc
2-2
S2
"BYPASS"
"Ein OK"
"NORM"
R36*
500Ω
"IND SPAN"
R37*
4.64k
M1*
0-1mA
mA
110Ω

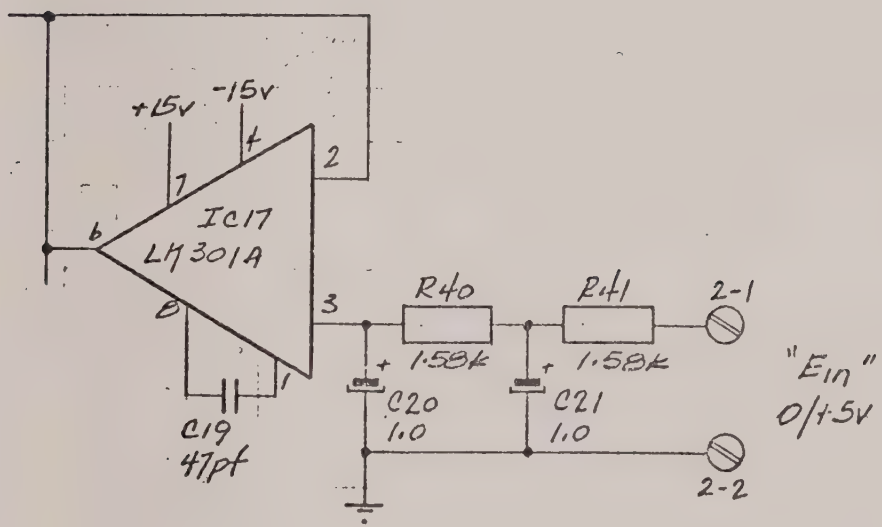
Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

IC12 is the output buffer circuit. This circuit isolates the Slope Generator circuitry from the possible effects of output loading. Upon inspection, it can be seen that, except for minor variation, IC12 is simply a non-inverting unity gain voltage follower, similar to IC9 and IC10. In this case, however, the output is limited to the range of -0.7v to +5.1v by zener clamping diode, CR5. C11 is the compensation capacitor for IC12. C10 serves to commonize the inputs of IC12 for ac noise signals. This permits the common mode rejection of the op amp to cancel these signals so that they will not appear in the output.

(Diagram IC12)

Meter M1 and its series resistors R36 and R37 are provided as a part of the Slope Generator Indicator/Control Station. A current of 1ma produces full scale deflection of the meter's indicating pointer. A current of 1ma will result when a +5volt signal is applied to R36, and when R36 is adjusted to provide a total series resistance of 5kΩ. The meter scale is typically calibrated -125°F to +375°F, with an equivalent °C scale, according to the response curve of a copper vs. constantan (Type T) thermocouple temperature sensor. As a result, it indicates temperature settings directly. The scale of the meter can, however, be calibrated to accommodate any curve and any system of engineering units.


+15v
-15v
7
4
2
IC17
LM301A
6
3
R40
R41
2-1
1.58k
1.58k
"Ein"
0/+5v
C20
1.0
C21
1.0
C19
47pf
2-2

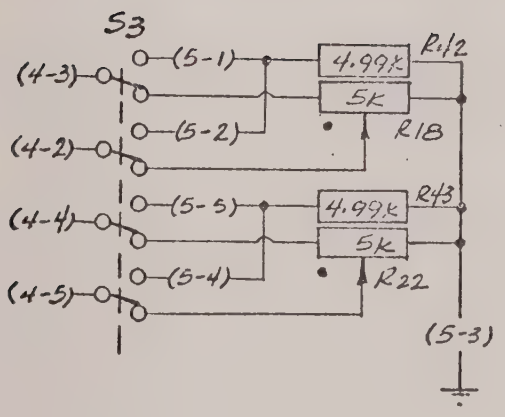
Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

Switch S2 provides a means of monitoring either the input signal or the output signal on Meter M1, and also a means of connecting the input setpoint signal directly to the output, thereby "bypassing" the Slope Generator. As can be seen, the Slope Generator provides its normal output when this switch is in either the "NORM" or "EinCK" position. In the "NORM" position, the meter indicates the value of the output signal, while in the "EinCK" position, the meter is connected to the input signal. In the "bypass" position, the input signal is connected directly to the output, and the meter reading is applicable to both the input and output.

IC17 Diagram

IC17 buffers the set point input signal, and is idential to IC12, except that this circuit is not clamped. In this case, a two section L-type filter is used to attenuate noise at the input terminals. Since the "reactance" of C20 or C21 is 159Ω for signals having a frequency of 1k Hz, each section of this filter acts like a voltage divider composed of a 159Ω element and a 1580Ω element. A noise signal at the input having a frequency of 10k Hz and an amplitude of 10 volts pk/pk, will appear at the R40, C21, R41 junction with its amplitude reduced by a factor of 100, to about 1mv pk/pk. As the noise frequency increases, the attenuation factor increases, and visa versa. For dc input voltages, the filter offers no attenuation, thereby preserving the accuracy of the input.


S3
(4-3)
(4-2)
(4-4)
(4-5)
(5-1)
(5-2)
(5-5)
(5-4)
4.99K
5K
4.99K
5K
R12
R18
R43
R22
(5-3)

Functional Analysis (Continued)

Pulse Forming Circuits (Continued)

(S3 Diagram)

The Indicator/Control Station also includes a third switch, S3, which allows remote programming of the slope rates. When this switch is in the "manual" position, R18 and R22 are connected in the circuit as shown on the Slope Generator schematic diagram. When this switch is in the "remote" position, remote programmable potentiometers are connected to IC9 and IC10 in place of R18 and R22. These remote potentiometers are connected to the terminal block on the back of the Indicator/Control Station.

It is permissible to provide remote program slope rate signals, 0v to ±1.666 volts, instead of remote program potentiometers.

Where this programming capability is not used, S3 can be used to provide one of two other functions. The switch can be wired so that in the "remote" position, it connects Pin 3 of IC9 and IC10 either to ground, or to the wipers of R16 and R20. The "remote" position provides the maximum ROC obtainable for the multiplier setting of S2. These options are achieved by connecting jumper wires at the terminal block on the back of the Indicator/Control Station. As delivered from the factory, the unit is normally wired to provide the fast ROC when S3 is switched to "remote".

The Slope Generator can be calibrated quickly and easily when the following test equipment is available:

- a stop watch
- an oscilloscope with an accurately calibrated time base
- a digital voltmeter capable of reading 2 volts to two decimal places.

These are the minimum requirements. If a frequency counter is available, it may be used to measure frequency and pulse width, and further simplify the effort. A common analog VOM should never be used in place of the DVM.

(1) Remove the cover from the Slope Generator by depressing its ends to release the catches.

(2) All input and output connections should be in their normal configuration for the system in question.

(3) Set the controls on the Indicator/Control Station as follows:

S1	:X.1mv
S2	:"NORM"
S3	:"MANUAL"
U/S Rate	:"999" + 1 (1000)
D/S Rate	:"999" + 1 (1000)

(4) If the system does not include an Indicator/Control Station, turn R18 and R22 fully clockwise, then inspect TB3 and TB4 to ascertain whether the unit has been wired for "X.1mv", "X1mv", or"X10mv" operation

(4) Continued.

Jumpered Terminals	Rate Range
TB3 - 1 to TB4 - 6	X0.1 mv
TB3 - 1 to TB4 - 7	X1.0 mv
TB3 - 1 to TB4 - 8	X10 mv

Note this connection, then rewire the unit for "X0.1mv" operation as above.

CAUTION

The Slope Generator circuit board assembly carries potentials of 115vac near TB1 and the power supply circuitry. Take care to AVOID these areas and the attendant DANGER OF SEVERE ELECTRICAL SHOCK.

WARNING

In control applications, the Slope Generator output is used to provide control voltage signals to REMOTE EQUIPMENT. Prior to proceeding, take steps to assure that any such equipment is POSITIVELY DISABLED, so that the random output produced during calibration will not cause such equipment to be operated in potentially dangerous modes.

(5) Apply power to the Slope Generator at TB1:

L = Line)
N = Neutral) 115vac 50/60 Hz
E = Earth)

Alignment and Calibration (Continued)

(6) Connect the DVM to the +15vdc power supply:

(+) lead to TP-1

(-) lead to TP-G

(7) Adjust R31 to provide a DVM indication of exactly +15.000 volts.

(8) Connect the DVM to the -15vdc power supply:

(+) lead to TP-2

(-) lead to TP-G

(9) Adjust R33 to provide a DVM indication of exactly -15.000 volts.

(10) Disconnect the DVM.

(11) Connect the oscilloscope to the 1 Hz clock circuit:

(+) lead to TP-3

(-) lead to TP-G

(Set the sweep rate to about 1 sec/cm and the vertical gain to about 5v/cm. Internal trigger.)

(12) The scope should display a square wave signal having a frequency of about 1.0 Hz and an amplitude of ±14vdc. If the calibration of the scope is reliable, set R3 as required to produce a frequency of exactly 1.0 Hz (one cycle per second). If the accuracy of the scope on this slow range is questionable, count cycles during a two minute interval using the stop watch to verify the frequency setting:

$$F = \frac{\text{cycles counted}}{120}$$

(13) Connect the scope to the output of the pulse forming circuits:

(+) lead to TP-4

(-) lead to TP-G

(Set the sweep rate to about 100 uS/cm and the vertical gain to about 5v/cm. Internal trigger.)

Alignment and Calibration (Continued)

(14) The scope should display a pulse having a recurrance rate of 2pps, an amplitude of ±7vdc, and a pulse width of 0.5ms. Adjust R11 to produce a pulse width of exactly 0.5ms.

(15) Switch S1 to the "X1mv" position.(For wired applications see Step 4 and reconnect the jumper wire.) The pulse width, as displayed on the scope should now be about 5.0ms. Adjust R9 to produce a pulse width of exactly 5.0ms (sweep rate set to 1ms/cm).

(16) Switch S1 to the "X10mv" position. (For wired applications see Step 4 and reconnect the jumper wire.) The pulse width as displayed on the scope, should now be about 50ms. Adjust R7 to produce a pulse width of exactly 50ms (sweep rate set to 10ms/cm).

(17) Disconnect the scope. Set S1 (or rewire) for "X.1mv".

(18) Connect the DVM to the negative precision reference voltage circuit:

(+) lead to TP-5

(-) lead to TP-G

(19) Adjust R16 to provide a DVM indication of exactly -1.666 volts.

(20) Connect the DVM to the positive precision reference voltage circuit:

(+) lead to TP-6

(-) lead to TP-G

(21) Adjust R20 to provide a DVM indication of exactly +1.666 volts.

(22) Set the input to the Slope Generator at its 0% value. Connect the DVM to the output terminals:

(+) lead to TB2 - 3

(-) lead to TB2 - 2

(23) The DVM indication should be between zero volts and +5 volts, and should be diminishing at a rate of about 100mv/minute. Verify this rate by measuing the time required for the output to diminish from one point to another, using the stopwatch and the DVM indication. The measuring interval should be at least two minutes. Compute the actual transition rate as follows, and record the result:

$$\text{Actual ROC} = \frac{E1 - E2}{\Delta t}$$

where:

E1 = Output voltage at t_o (volts)

E2 = Output voltage at the end of the timing interval (volts)

Δt = Length of timing interval (minutes)

ROC = Volts per minute

(24) Now check the upscale transition rate by setting the input at +5 volts, and timing a transition as per Step 23 above. Record the calculated transition rate.

(25) Inspect the results of Steps 23 and 24.

a. If <u>both</u> the upscale and downscale transition rates are too fast or too slow, the adjustment of R11 must be corrected. Compute the correction factor as follows:

$$\text{factor} = \frac{\pm\text{ROC (mv/min)}}{100}$$

Now reconnect the scope to TP-4 and measure the pulse width. Multiply the measured pulse width times the

(25) Continued:

a. correction factor and re-adjust R11 to produce this new pulse width.

b. If the upscale and downscale transition rates are not equal, but both too high or too low, correct the smaller error, using the above procedure. Then correct the upscale - downscale difference using the following procedure.

c. If only one of the transition rates is incorrect, or to correct the error which remains in one direction after having recalibrated PW to correct for the smaller error in the opposite direction, calculate a correction factor as follows:

$$\text{factor} = \frac{\text{ROC(mv/min)}^*}{100}$$

*If the pulse width has been recalibrated, multiply the ROC which includes the larger error by the correction factor previously calculated in Step 25a, and use the result in the above formula.

If correcting the upscale ROC, connect the DVM to TP-5. If correcting the downscale ROC, connect the DVM to TP-6. Multiply the DVM indication (approx. ±1.666v) by the correction factor computed immediately above. Readjust either R16 (D/S cal) or R20 (U/S cal) to produce the indication calculated here.

(26) If desired, the transition rates may now be rechecked by repeating Steps 23 and 24.

(27) If it was necessary to recalibrate the "X0.1mv" range, it is likely that the "X1.0mv" and "X10mv" ranges would have proven to be inaccurate by about the same factor. Since the adjustment of R11, R18 and R22 affects the calibration of all three ranges, all three should now be correct. If desired, however, the "X1,0mv" and "X10mv" may be tested and, if necessary, recalibrated by means of R9 and R7, respectively. If calibrating these ranges, the divisor used in the formula given in Step 25a will be 1000 and 10,000, respectively. Only the pulse width may be recalibrated on these ranges; R11, R16 and R20 must not be moved. If measurements indicate a u/s vs. d/s differential rate error, this indicates that the "X0.1mv" scale was recalibrated incorrectly, and that procedure should be carefully repeated.

(28) If the system includes an Indicator/Control Station, set S1 to "bypass" and connect the DVM to the output:

(+) lead to TB2 - 3

(-) lead to TB2 - 2

Set the output to exactly zero volts. (Be sure to zero the DVM.) Then adjust the mechanical zero adjustment on the face of the meter as necessary to set its indicating pointer exactly over the left-end scale mark (0%). Then set the output to exactly +5.000 volts and adjust R36, on the back of the Indicator/Control Station as necessary to set the indicating pointer exactly over the right-end scale mark (100%).

(29) This completes the calibration procedure. For units which do not include an Indicator/Control Station, refer back to Step 4 and reconnect the jumper wire as per its original connection. Disconnect all test equipment and remove power from the Slope Generator prior to replacing its cover. If remote equipment was disabled during the calibration procedure, be certain to restore it to operable condition.

ALTERNATE PROCEDURES

Unless a good laboratory oscilloscope is available, it might be difficult to achieve accurate measurements of pulse width.

If a frequency counter is available, its use can greatly simplify frequency and pulse duration measurements, and better accuracy should result.

In the absence of either a good scope or a frequency counter, an accurate DVM may be used to measure the pulse widths. In this case, connect the DVM:

(+) lead to TP-4A

(-) Lead to TP-G

The voltage at this point is related to the pulse width by a factor of 0.1v/ms:

S1 Position	PW	TP-4A
X10	50ms	5.00v
X1	5ms	.500v
X.1	.5ms	.050v

Use these voltage measurements in place of the pulse width measurements in Steps (13) through (16), and in Step (25).

MAINTENANCE

The SlopeGenerator requires no periodic maintenance, as such. Good maintenance practice suggests that the unit be inspected from time to time for contamination, loose connections, etc. The practical inspection interval will vary with the application and the nature of the environment in which the unit is used.

If necessary, blow accumulations of dust out of the unit using compressed air (30psi max.). In extreme cases all parts of the unit except the meter may be cleaned of accumulated dirt using a chlorthene or freon solvent, followed by a thorough rinse with demineralized water. Insure that the unit is thoroughly dried out prior to reassembly and return to service.

The desired calibration interval must also be established by the user. In this type of equipment component aging is usually responsible for calibration drift. In the case of the Productsaver however, the use of top quality solid state and passive components minimizes the probability of such variation, and should be considered when establishing calibration varification requirements.

When the equipment was designed, the importance of reliability in this type of instrumentation was recognized. For this reason the circuit includes a high level of redundancy. Only top quality component parts are used in its construction, and each part is conservatively rated. If and when failures do occur, troubleshooting is simplified by the fact that most of the individual circuits within the unit consist of an integrated device. These devices typically combine forty to seventy circuit elements into a single replaceable package, leaving only a few discrete components on the outside. Furthermore, each section of the circuit usually performs a single, clearly identified function, and it is therefore fairly simple to work thru the entire circuit on a GO/NO–GO basis until the faulty circuit is isolated.

When troubleshooting becomes necessary, there is simply no substitute for knowledge. With this in mind, a comprehensive explanation of the circuit is provided in this manual under the heading FUNCTIONAL ANALYSIS. This explanation includes the designed purpose of every electronic component part. Sometimes a visual inspection of the circuitry will locate the fault in short order. Where this is not the case, poking around in unfamiliar circuitry and replacing suspect parts usually wastes a lot of time and a lot of parts. In such cases, it is usually much more expedient to simply sit down for an hour or two and study the circuitry until it is reasonably well understood, prior to doing any actual troubleshooting.

When troubleshooting any electronic circuit, its dc power supplies must always be tested for proper operation as THE FIRST STEP. the output of these supplies should be within 1% of their assigned values, except for the 30vdc unregulated supply, which may vary by ±15%. Other than this, and because of our philosophy, as expressed above, Thermotron has provided no 'troubleshooting guide' as such, in this manual.

SERVICE

Where troubleshooting assistance is required, phone or write Thermotron - ACS Customer Service (see back cover).

Users desiring to return units for service at the factory should contact Thermotron - ACS Customer Service in advance for a returned goods authorization number. Returned units shoud be CAREFULLY PACKED TO PREVENT DAMAGE IN SHIPMENT. Double packing (two cartons, each with excelsior all around the contents) is recommended.

All returns should be accompanied by a purchase order showing the Thermotron returned goods authorization number, return shipment instructions, the nature of the service requirement (what seems to be wrong, with as much detail as possible), and the name of a person at the customer's plant who can be contacted for further information.

All shipping related to service is handled FOB Holland, Michigan. UNITS ARRIVING AT HOLLAND IN AN APPARENTLY DAMAGED CONDITION OR WITHOUT PRIOR AUTHORIZATION CAN NOT BE RECEIVED. All units accepted for service will receive immediate attention at the factory, with 24-hour turn-arounds provided in many cases. Unless otherwise specified on your order, outbound repaired units will be shipped using the same method as the inbound shipment.

Orders for service parts should also be directed to Thermotron - ACS Customer Service. All parts are normally stocked at the factory, and in most cases 'same-day' shipment can be provided. In order to expedite service and assure that the correct parts are shipped, all items should be identified by the Thermotron six-digit part number (IISS number), in addition to their noun and spec.

e.g.

052347 RESISTOR, Film 2.4K ¼w 1%

- Photo Req'd -

PARTS LIST

Slope Generator Assy.
013008

IISS	Description	Qty
048030(1)	PCB ASSY., Slope Gen	1
251005	GROMET, 3/16 x 5/16 x 1/16	2
251006	GROMET, 1/2 x 3/8 x 1/16	1
271005	SCREW, Bdr.Hd. 4-40 x 3/8	6
272003	WASHER, Flt #4	6
273002	LOCKWASHER, Int #4	6
279005(2)	THREADSPACER, 4-40 x 1/4	6
351011(2)	CHASSIS, S.G.	1
353008	COVER, S.G.	1
451008	USER'S MANUAL	1

(1) Illustrated parts breakdown provided for these items.

(2) Not independantly replacable. Order both 279005 (6) and 351011 (1).

- Photo Req'd -

PARTS LIST

PCB Assy., Slope Generator

048030

IISS	Description	Qty
051784	RESISTOR, W.W. 3.0Ω 2w 5%	1
051785	RESISTOR, 5.1Ω	1
052205	RESISTOR, Film 110Ω 1/4w 1%	1
052234	RESISTOR, 221Ω	3
052249	RESISTOR, 316Ω	2
052321	RESISTOR, 1.58k	2
052338	RESISTOR, 2.43k	2
052341	RESISTOR, 2.61k	2
052390	RESISTOR, 8.45k	1
052401	RESISTOR, 10k	2
052411	RESISTOR, 12.7k	1
052466	RESISTOR, 47.5k	1
052501	RESISTOR, 100k	6
052515	RESISTOR, 140k	1
052508	RESISTOR 118k	1
052513	RESISTOR, 133k	1
052568	RESISTOR, 499k	1
054001	POTENTIOMETER, Trim 100Ω 25T	4
054003	POTENTIOMETER, 2k	2
054004(1)	POTENTIOMETER, 5k	1
054010	POTENTIOMETER, 25k	1
062001	CAPACITOR, Disc. 47pf 1kv	8
062004	CAPACITOR, .01uf 100v	2
063002	CAPACITOR, Tant. 1.0uf 50v	5
063003	CAPACITOR, 4.7uf	1
064002	CAPACITOR, Elec. 250uf 50v	2
067001(2)	CAPACITOR, Poly. 1.0uf 50v	2
067002(2)	CAPACITOR, 10uf 50v	1

PARTS LIST (Continued)

PCB Assy., Slope Generator

048030

IISS	Description	Qty
071001	TRANSFORMER, Pwr, 115v/40vct	1
081007	DIODE, Rect. 1N4002	6
081008	DIODE, Zen. MZ500-9	3
081011(3)	DIODE, MZ500-17	2
083003	TRANSISTOR, Pwr 2N4898	2
083006(2)	TRANSISTOR, FET 2N4339	2
093001	I.C., Op Amp LM301AH	14
093003	I.C., Pos Reg LM305AH	1
093004	I.C., Neg Reg LM304H	1
093007(2)	I.C., Op Amp LH0022CH	1
176002	TERMINAL BLOCK, 3-w SEPCR	1
176003	TERMINAL BLOCK, 3-w EPCR	1
176008	TERMINAL BLOCK, 8-w SEPCR	2
179001	SOLID PIN, PCB	9
201037	PTD. CKT. BOARD	1
233006	HEAT SINK, TO-66 Flt	2
271005	SCREW, Bdr.Hd. 4-40 x 3/8	4
273007	LOCKWASHER, Int. #4	4
274002	NUT, Hex #4	4

(1) Qty reqd is 3 if 013009, or equiv., is not provided.

(2) Failure to use exact replacements may radically degrade performance and produce unsafe operating modes.

(3) CR5 is selected for V2 of 5.1 to 5.5vdc.

(PHOTO REQ'D)

PARTS LIST
Slope Gen. Indicator/Control Station
013009

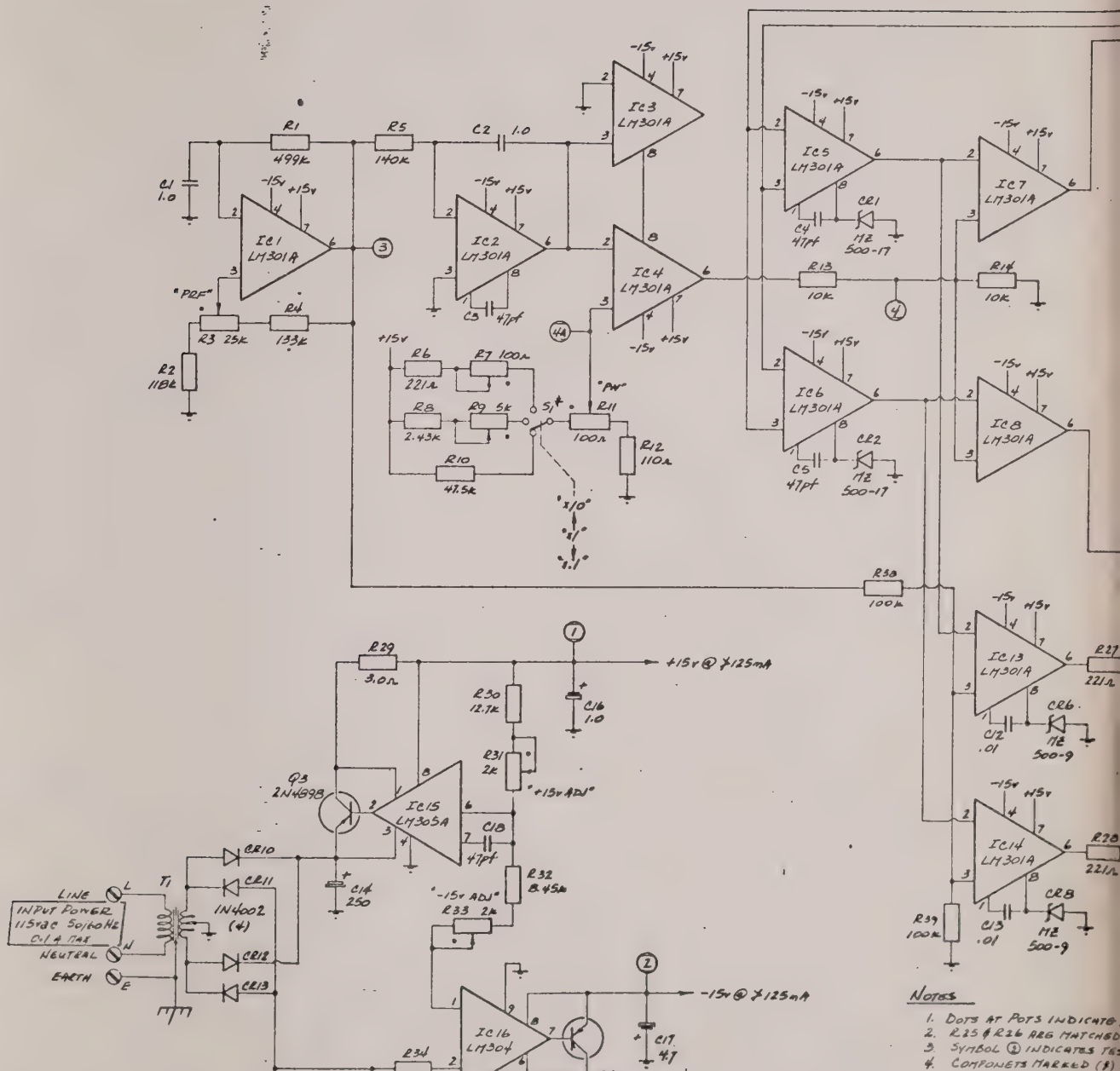
IISS	Description	Qty
052368	RESISTOR, Film 4.64k 1/4w 1%	1
052368(1)	RESISTOR, 4.99k	2
054011	POTENTIOMETER, Dial 5k	2
054012	POTENTIOMETER, Trim 500Ω 1T	1
081012	DIODE, LED OSL-3	2
101001	SWITCH, Toggle 2P3T	2
101006	SWITCH, 4P2T	1
123004(2)	METER, Temp. -125/+375°F T	1
176012	TERMINAL BLOCK, 5-w SEIFC	1
194004	CABLE CONTROL, 20-c x 4 ft.	1
198003	CABLE TIE, 0 - .75	2
198005	SHRINK TUBE 3/32 x .5001g. wht	48
251006	GROMET, 1/2 x 3/8 x 1/16	1
254001	HOLDER, LED	2
271065	SCREW, Fl.Hd. 4-40 x 3/8	2
272003	WASHER, Flt. #4	2
272004	WASHER #6	4
273002	LOCKWASHER, Spt. #4	2
273003	LOCKWASHER, Spt. #6	4
274002	NUT, Hex #4	2
274003	NUT, #6	4
351010(2)	PANEL CONTROL, S.G.I.C. (°F/min)	1
352004	CHASSIS, S.G.I.C.	1
353007	COVER, S.G.I.C.	1
451008(3)	USER'S MANUAL	-

(1) Not reqd. for programmed applications.
(2) Other ranges will have a different part number.
(3) Provided with Slope Generator 013008.

PARTS LIST, Symbolic

C1	067001
C2	067001
C3	062001
C4	062001
C5	062001
C6	062001
C7	062001
C8	067002
C9	063002
C10	063002
C11	062001
C12	062004
C13	062004
C14	064002
C15	064002
C16	063002
C17	063003
C18	062001
C19	062001
C20	063002
C21	063002
CR1	081011
CR2	081011
CR3	081007
CR4	081007
CR5(1)	081008
CR6	081008
CR7	081012
CR8	081008
CR9	081012
CR10	081007
CR11	081007
CR12	081007
CR13	081007
IC1	093001
IC2	093001
IC3	093001
IC4	093001
IC5	093001
IC6	093001
IC7	093001
IC8	093001
IC9	093001
IC10	093001
IC11	093007
IC12	093001
IC13	093001
IC14	093001
IC15	093003
IC16	093004
IC17	093001
M1	123004
Q1	083006
Q2	083006
Q3	083003
Q4	083003
R1	052568
R2	052508
R3	054010
R4	052513
R5	052515
R6	052534
R7	054001
R8	052338
R9	054004
R10	052466
R11	054001
R12	052205
R13	052401
R14	052401
R15	052341
R16	054001
R17	052249
R18	054011
R19	052341
R20	054001
R21	052249
R22	054011
R23	052501
R24	052501
R25	052501
R26	052501
R27	052234
R28	052234
R29	051784
R30	052411
R31	054002
R32	052390
R33	054003
R34	052338
R35	051785
R36	054012
R38	052501
R39	052501
R40	052321
R41	052321
S1	101001
S2	101001
S3	101006
TB1	176003
TB2	176002
TB3	176008
TB4	176008
TB5	176012
T1	071001

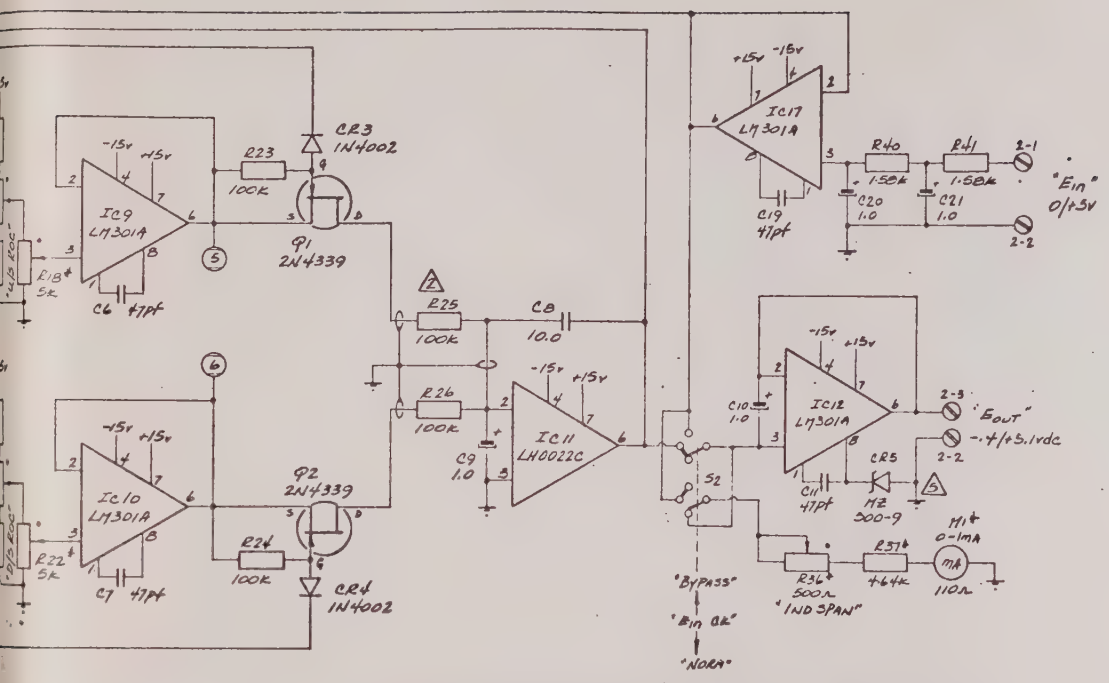
(1) Select CR5 for V2 = 5.1 to 5.5vdc.



Notes

1. Dots at Pots indicate
2. R25 & R26 are matched
3. Symbol ① indicates Te
4. Components marked (*)
   R18 & R22 are mou
   Operator Roc adj
   Connections will
   interconnecting
5. CR5 must be selected

SYSTEM SCHEMATIC DIAGRAM
SLOPE GENERATOR (TM)
REV: 01/30/08 & 01/30/09
470217



No.	Date	Init.	REVISIONS
1	12/01/A	KJ	S1 CHANGED TO 4 WAY SWITCH 10 POS. 90° OPERATION
2	1/04/B	KJ	INPUT BUFFER, IC17, ADDED
3	1/30/08	KJ	470 OHM RESIS., S2 DIAG., R37 & R39, ADJ RANGE TABLE
4	1/30/09	KJ	CORRECT TB4 CONNECTION DATA
5	2/04/09	KJ	FINAL PROD. PILOT COMPLETED

(TM) TRADEMARK - THERMOTRON CORPORATION

CALIBRATION & MINIMUM PERFORMANCE DATA

TEST PT	OBSERVATION	TOL	ADJ
1	+15vdc	± 10mV	R31
2	-15vdc	± 10mV	R33
3	+14v, 0, -14v, 1.0Hz	E_{PK}: ±.5v FREQ: ±.25%	(IC11) R3
4	PRF=2Hz, +7v, -7v, PW = 50±5% Pos.	PRF: ±.25% E_{PK}: ±1v PW: ±.5%	(R3) R11 R7 OR R9 AS APPL.
4A	+0.5v AS1 POSITION (ALT. TO #4 ABOVE)	±.1%	R11 R7 OR R9 AS APPL
5	-1.667 vdc*	± 8mV	R16
6	+1.667 vdc*	± 8mV	R20

* R18 & R19 SET TO "999" ±1 CL FULLY CLOCKWISE
– ALWAYS PERFORM TESTS IN THIS ORDER. REFER TO USER'S MANUAL 45108 FOR DETAILS.

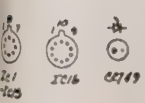
WIRING INFORMATION

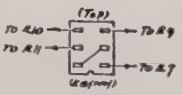
TERM #	CKT
TB1-L	LINE
-N	NEUTRAL
-E	EARTH
TB2-1	Ein (+)
-2	Gnd
-3	Eout (+)
TB3-1	S1-R11
-2	S2-IC11
-3	IC17-S2
-4	R28-CR9
-5	R27-CR7
-6	n/c
-7	S2-IC12
-8	Gnd (+)
TB4-1	ISO Gnd
-2	R18-IC9
-3	R16-R18
-4	R20-R22
-5	R22-IC10
-6	R10-S1
-7	R9-S1
-8	R7-S1.

* Gnd connection for CR7 & CR9 only.

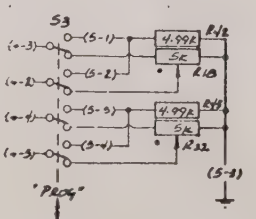
…POSITION OF WIPER.
…±.05% (HEAT SINK WHILE SOLDERING).
…WIL. TO CALIB. PROCEDURE OR MIN. PERFORMANCE CHECK.
…NTED REMOTE FROM PCB ASSY 046030 IF USED.
…THE CIRCUIT BOARD IN CASES WHICH DO NOT REQUIRE …CAPABILITIES. WHEN S1 AND/OR S2 ARE OMITTED, THESE …WIRED" AS APPLICABLE TO THE APPLICATION. REFER TO …DIAGRAM FOR DETAILS.
…R to 5.5vdc.

…ons).



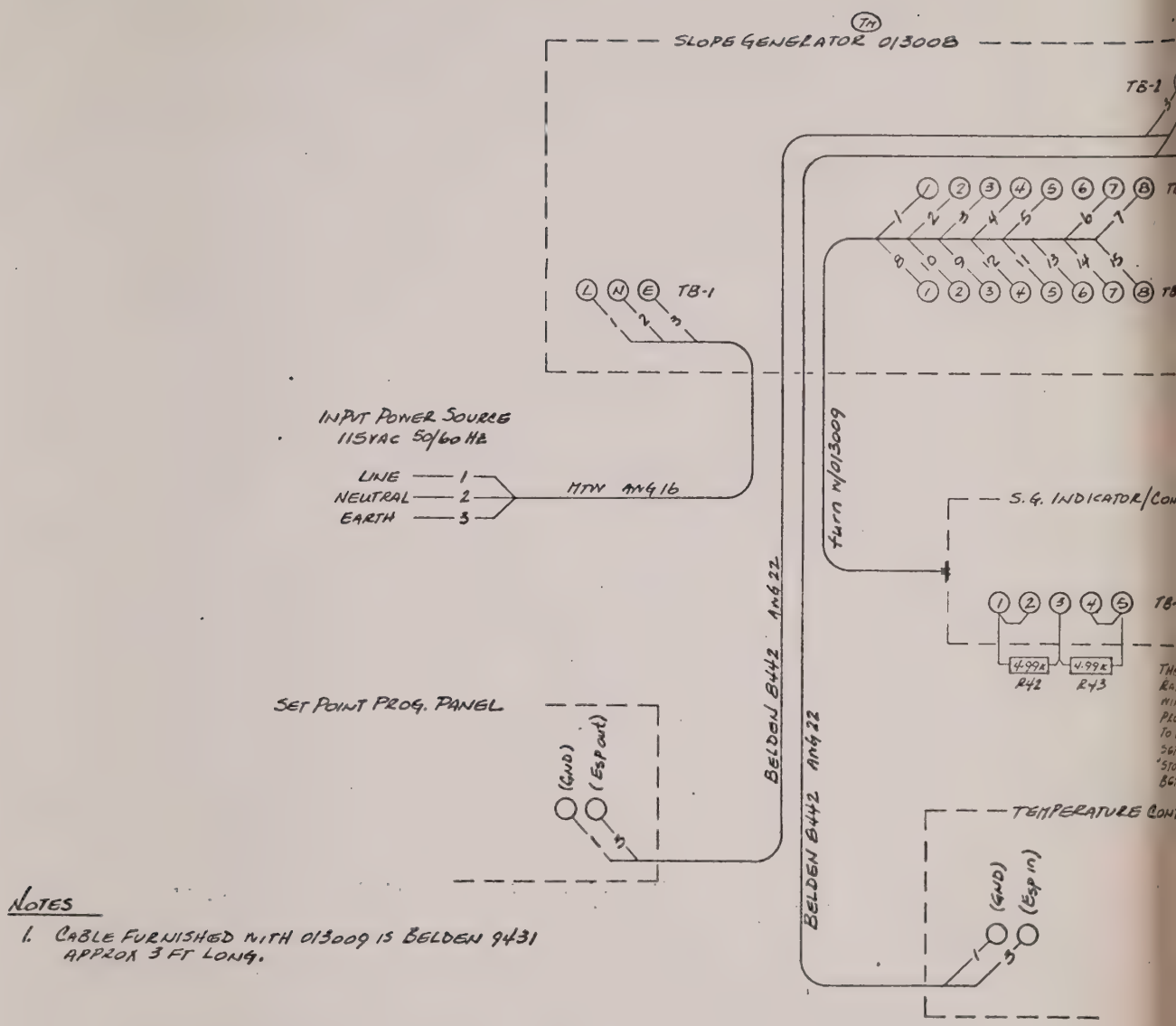


S1 WIRING INFO



STANDARD WIRING FOR S3. FOR DETAILS SEE DWGS 470224 & 470225

THERMOTRON
HOLLAND, MICH. USA

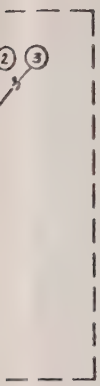


NOTES

1. CABLE FURNISHED WITH 013009 IS BELDEN 9431 APPROX 3 FT LONG.

THERMOTRON CORPORATION
HOLLAND, MICHIGAN 49423

NO	CHANGES	DATE	BY	CHKD
1	[illegible]	[illegible]	[illegible]	
2	[illegible]	[illegible]	[illegible]	
3	[illegible]	[illegible]	[illegible]	



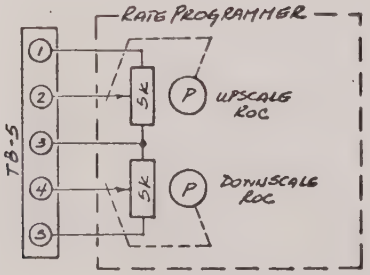
L ASSY 013009

TERMINALS FOR TRANSITION
PROGRAMMER. FOR PROGRAMMER
G SEE EXAMPLE BELOW. IN NON-
AMMED SYSTEMS WIRE AS SHOWN TO
OVIDE RATE EQUAL TO "1000" DIAL
GS WITH S3 IN "PROG" POSITION. FOR
HOLD" OPTION RECONNECT JUMPERS
EEN 2 & 3 AND 3 & 4.

OLLER

IPCEA COLOR CODE	
1	BLK
2	WHT
3	RED
4	GRN
5	ORG
6	BLU
7	WHT/BLK
8	RED/BLK
9	GRN/BLK
10	ORG/BLK
11	BLU/BLK
12	BLK/WHT
13	RED/WHT
14	GRN/WHT
15	BLU/WHT
16	BLK/RED
17	WHT/RED
18	ORG/RED
19	BLU/RED
20	RED/GRN

(INSULATED PWR CABLES ENG. ASSN)



TYPICAL RATE PROGRAMMER CONNECTIONS

	DATE	BY	CHKD

TOLERANCE

SCALE —

MATERIAL AS NOTED

FINISH —

DESCRIPTION: TYPICAL WIRING INFORMATION FOR SLOPE GENERATOR™ SET POINT SYSTEMS

REF: 013008 & 013009

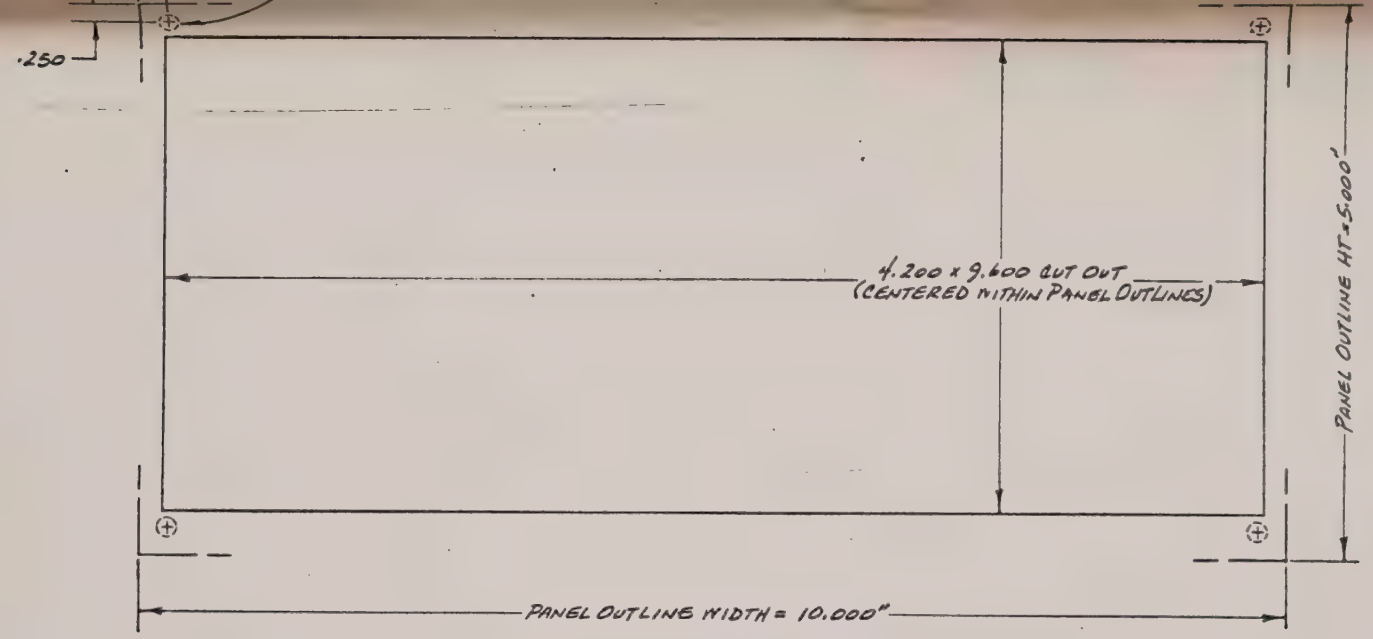
DRAWN BY GRAINGER DATE 12 Oct 72

CHECKED BY DATE

RELEASED BY DATE

470224

™ TRADE MARK - THERMOTRON CORP, HOLLAND MICH 49417 USA 1972



MOUNTING INFORMATION FOR MODEL 013009
SLOPE GENERATOR® INDICATOR/CONTROL STATION

NOTE: ZERO CLEARANCE REQD AT TOP AND BOTTOM, ONE INCH MIN CLEARANCE REQD ON BOTH SIDES. AFT SECTION PROTRUDES APPROX 3" BEHIND MOUNTING SURFACE. ACCESS TO REAR PANEL REQD FOR WIRING AND CALIBRATION.

TELEDYNE
CORPORATION
HOLLAND, MICHIGAN 49423

NOM. BOX OUTLINE WIDTH = 6.000"
4 MOUNTING HOLES EQUALLY SPACED WITHIN OUTLINE RECTANGLE ON 4" x 11" CENTERS. NO. 6-32 FASTENING HARDWARE (PAN OR BINDER HEAD SCREWS) RECOMMENDED. USE 5/32 DIA (.156) HOLE TO CLEAR 6-32 SCREW, OR TAP, AS REQUIRED.
NOM. BOX OUTLINE LENGTH = 12.000"

MOUNTING INFORMATION FOR SLOPE GENERATOR™ MODEL 013008

NOTE: ONE INCH CLEARANCE REQUIRED EITHER END AND ALONG FRONT EDGE. TOP OF BOX PROTRUDES APPROX 2.5" ABOVE MOUNTING SURFACE. MAINTAIN ACCESS TO TOP OF BOX TO ALLOW REMOVAL OF COVER FOR WIRING AND CALIBRATION.

MOUNTING HOLES EQUALLY SPACED AT EACH CORNER. NO. 6-32 FASTENING

CHANGES	DATE	BY	CHKD
NONE	10 OCT 72	G.	

NO	CHANGES	DATE	BY	CHKD

TOLERANCE	n/a.
SCALE	1 X SIZE
MATERIAL	n/a
FINISH	—
DRAWN BY	GARNER
CHECKED BY	
RELEASED BY	

DESCRIPTION
SLOPE GENERATOR™
MOUNTING INFORMATION

REF: 013008 & 013009

DATE: 6 OCT 72
DATE
DATE

470229

™ TRADEMARK THERMOTRON CORPORATION

THERMOTRON CORPORATION

1979

TAPE COMMAND II

THERMOTRON

TAPE COMMAND II

8 CHANNEL TAPE PROGRAMMER

General Description

The Thermotron Tape Command is a tape programmer. It is used to provide synchronous control of test program functions. Some of the functions that are normally programmed are:

Stopping or starting a temperature cam.

Controlling a wet bulb controller cam.

Stopping or starting a shaker.

Selecting remote temperature set pots.

Controlling injection solenoids.

Turning product power ON and OFF.

Regulating air flow with remote set pots.

Stopping or starting a vacuum pump.

Controlling air conditioning units (ECA's).

Controlling functions of other chambers and ECA's.

Up to eight of these functions may be simultaneously programmed on a standard one inch wide, eight level, perforated tape.

Tape Programming

The tape is divided into eight levels (channels) of programming information. One level is required for each test function that must be programmed.

The program information is in the form of a hole which is punched in one level of the paper tape. This hole allows the selected channel transistor switching circuit to be activated, causing the associated relay to pull-in, switching the output contacts causing the desired program function to be performed. It is

Tape Programmer - Continued

therefore possible to program up to eight functions by providing up to eight holes in the program tape.

A hole in any one level will constitute an ON signal. The absence of a hole will be read as an OFF signal. If there are no holes punched in the tape, the position of the MODE switch will determine which of two actions will be performed. In the ONE CYCLE position, the tape will stop its advance and the EOP (End of program) light will come on. In the REPEAT position, the program will advance to the next line on the tape.

Synchronization is provided by the sprocket holes near the center of the program tape. These sprocket holes are punched at the same time the program tape is punched and aligned with the holes of the program information.

Tape Reader

The Tape Reader is extremely simple to operate. Only one operation is required to remove or install the tape. A gray plastic release catch appears on the read head cover. Applying pressure to this catch will release the clear plastic hold-down, thus releasing the tape.

TAPE COMMAND II

Control Panel

The control panel contains the following indicator lights.

PWR	Indicates power is on.
TAPE	Indicates no tape on tape head or improperly positioned tape.
EOP	End of program.
1 - 8	Indicates the activated channel.

There are three switches on the front panel. One of these is the power switch and is marked ON-OFF. One switch has been provided to advance the tape one line each time it is actuated. This enables the tape to be adjusted to the line desired for program start. The other switch is the three position mode switch. When in the REPEAT position, the Tape Command will repeat a program until manually stopped. When in the HOLD position, no power will reach the tape drive and the program will not advance. In the ONE CYCLE position, the Tape Command will be stopped by a line of tape with no holes punched. If the switch is in the REPEAT position, line with no holes will automatically be advanced until a punched line is reached.

Preparing the Tape

Program tapes can be prepared by punching one hole at a time using an Ohr-tronics* Model 124 punch, or one line at a time using a Remex RTP-1 punch, or any equivalent type of punch.

* MDS Corporation

TAPE COMMAND II

Preparing the Tape - Continued

The program should be laid out on an interval of elapsed time format. One line of tape must be punched for each interval of the program. Each successive line must be punched identically to the last line as long as the program remains unchanged. When the program requirements change, the number of holes and their locations change.

It is possible to prepare a program tape using a TWX machine as a punch. A typical copy of the code is shown on the following page. This code may vary slightly between models of TWX machines. Other tape controlled office machines or computers may also be used to punch the program tape if the correct code is available on the machine.

NOTE: No holes stop tape in ONE CYCLE position. Tape will automatically advance if Tape Command is in REPEAT position.

CODE TO PUNCH CHANNELS

TWX	PROGRAM	TWX	PROGRAM
A	1 7	V	2 3 5 7
B	2 7	&	2 3 6 8
D	3 7	z	2 4 5 7
H	4 7	*	2 4 6 8
P	5 7	2	2 5 6 8
Space	6 8	\	3 4 5 7
C	1 2 7 8	,	3 4 6 8
E	1 3 7 8	4	3 5 6 8
I	1 4 7 8	8	4 5 6 8
Q	1 5 7 8	0	1 2 3 4 7 8
1	1 6	W	1 2 3 5 7 8
F	2 3 7 8	!	1 2 3 6
J	2 4 7 8	[	1 2 4 5 7 8
R	2 5 7 8	+	1 2 4 6
"	2 6	3	1 2 5 6
L	3 4 7 8	]	1 3 4 5 7 8
T	3 5 7 8	-	1 3 4 6
$	3 6	5	1 3 5 6
X	4 5 7 8	9	1 4 5 6
(	4 6	↑	2 3 4 5 7 8
0(zero)	5 6	.	2 3 4 6
G	1 2 3 7	6	2 3 5 6
K	1 2 4 7	:	2 4 5 6
S	1 2 5 7	<	3 4 5 6
#	1 2 6 8	←	1 2 3 4 5 7
M	1 3 4 7	/	1 2 3 4 6 8
U	1 3 5 7	7	1 2 3 5 6 8
%	1 3 6 8	;	1 2 4 5 6 8
Y	1 4 5 7	=	1 3 4 5 6 8
)	1 4 6 8	>	2 3 4 5 6 8
1	1 5 6 8	?	1 2 3 4 5 6
N	2 3 4 7	@	7 8

NOTE: Channels 1 thru 6 may be programmed on a TWX machine on a controlled sequence. Channels 7 and 8 cannot be controlled. If a TWX tape is used it may be necessary to leave channels 7 and 8 open.

The following key differences appear on the 33ASR TWX machine as opposed to the above listing.

Symbol	Key
\	FORM
[	VT
]	M (Shifted)

TAPE COMMAND II

Operating Instructions

These instructions will assist the operator in placing this tape programmer in operation.

Before attempting to operate this unit, the operator should make himself familiar with the instructions and procedures in this manual and all prints and diagrams concerned with this equipment.

1. Place the mode switch in the HOLD position.
2. Press the release catch on the tape reader head to release the tape hold-down.
3. Place the program tape on the tape reader sprocket ahead of the start of the program.
4. Place the tape hold-down in position over the tape and allow release catch to secure hold-down in place.
5. Place mode switch in ONE CYCLE position and actuate the advance tape switch until the tape is at the start of the cycle. Return mode switch to HOLD position.
6. After the chamber has stabilized, select either REPEAT or ONE CYCLE on the mode switch.

Preventive Maintenance

The Thermotron Tape Command has been designed so a minimum amount of maintenance will be required. Follow normal industrial cleaning procedures.

TAPE COMMAND II

Service

The best service tool is a thorough understanding of the unit to be serviced.

Before attempting to perform any maintenance of the Tape Command tape programmer, you should become thoroughly familiar with the procedures in this manual and the associated diagrams.

The following trouble shooting chart will serve as an aid in performing some of the maintenance work encountered in the operation of this equipment.

Symptom	Probable Cause	Action Required
1. Equipment inoperative. PWR light does not come ON.	1. Defective fuse.	1. Remove the power from TB1. Replace fuse and take a resistance reading across the line. If there is a direct short, it must be located and removed befor turning on the power. The normal resistance across the line is approximately 3 ohms.
2. Power light ON, but none of the channel lights come ON.	2. A. Transformer open. B. Rectifier shorted.	2. A. Take ohmmeter readings. Transformer primary should read approximately 3 ohms. Secondary should read approximately .5 ohms. Check for primary to secondary short or primary/secondary short to ground. B. Check the front to back resistance ratio of the individual diode in the bridge circuit. A good diode will have a front to back resistance ratio of 10:1 or more.

Service - Continued

Symptom	Probable Cause	Action Required
3. Tape does not advance automatically. (Will advance manually.)	3. A. Timer motor inoperative. B. Micro-Switch defective.	3. A. Make visual inspection of motor. See if the micro switch cam is turning. Determine if power is being supplied to motor. If there is power, the motor is probably defective. If there is no power, check F-1. B. Manually operate micro-switch and check with voltmeter or ohmmeter.
4. Tape does not advance automatically or manually.	4. Defective advance solenoid.	4. Take ohmmeter reading. Should be approximately 100 ohms.
5. Control relay on one channel does not energize.	5. A. Defective relay. B. Defective component in the channel transistor switching circuit. C. Star wheel does not drop into hole. D. Sensing pin does not protrude through holes in tape.	5. A. Substitute a relay from an adjacent channel. B. Replace defective circuit component. C. Repair or replace teletype tape reader head as necessary. D. Repair or replace teletype tape reader head as necessary.

Z

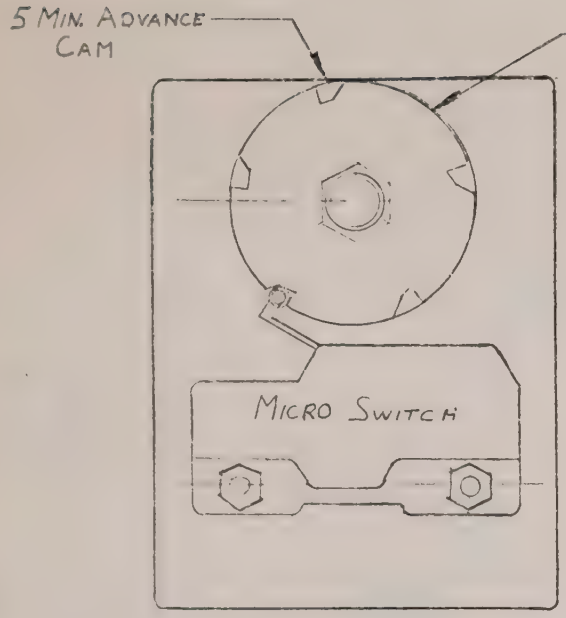


FIG. -1

MICRO - SWITCH - CAM ASSEY.
SIDE VIEW

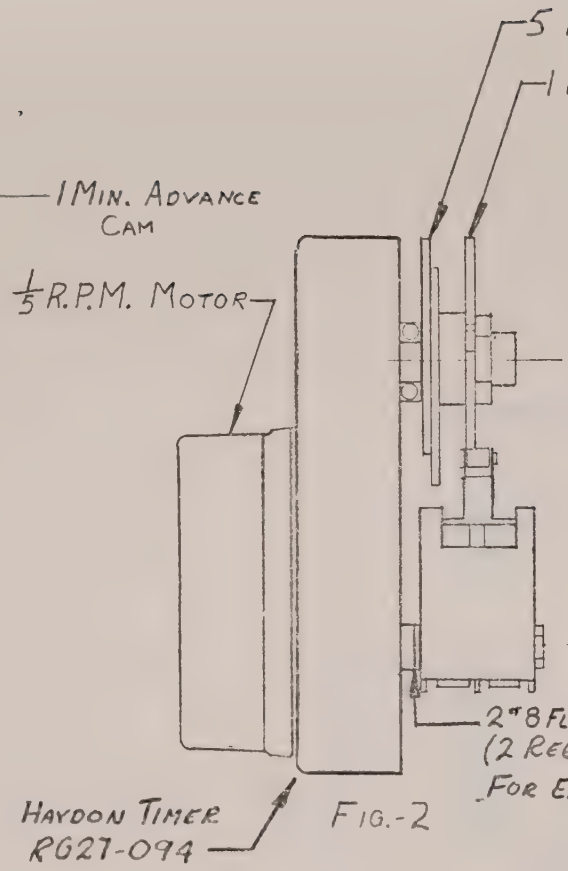


FIG. -2

MICRO - SWITCH - CAM ASSEY.
CAM SET FOR ONE MIN ADVANCE

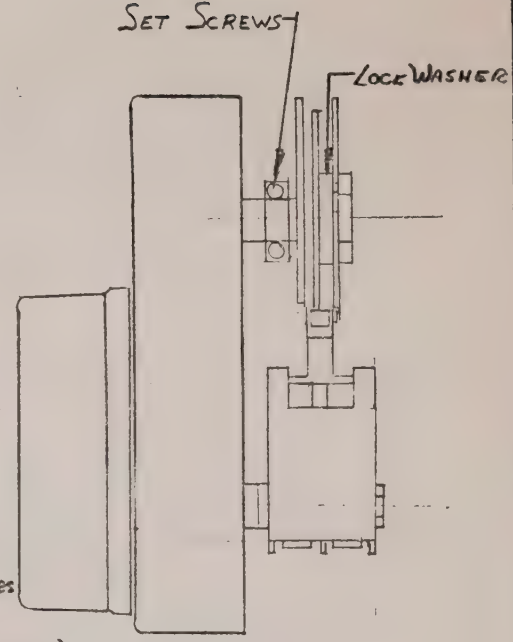


FIG. -3

MICRO - SWITCH - CAM ASSEY.
CAM SET FOR FIVE MIN ADVANCE

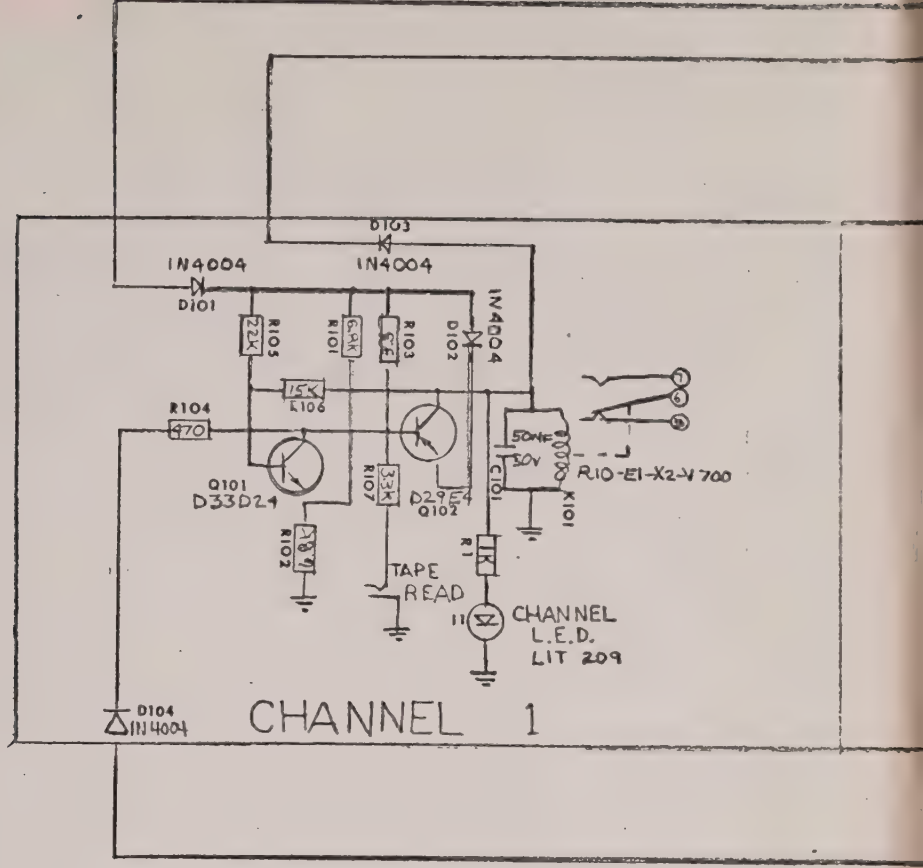
W.O.#

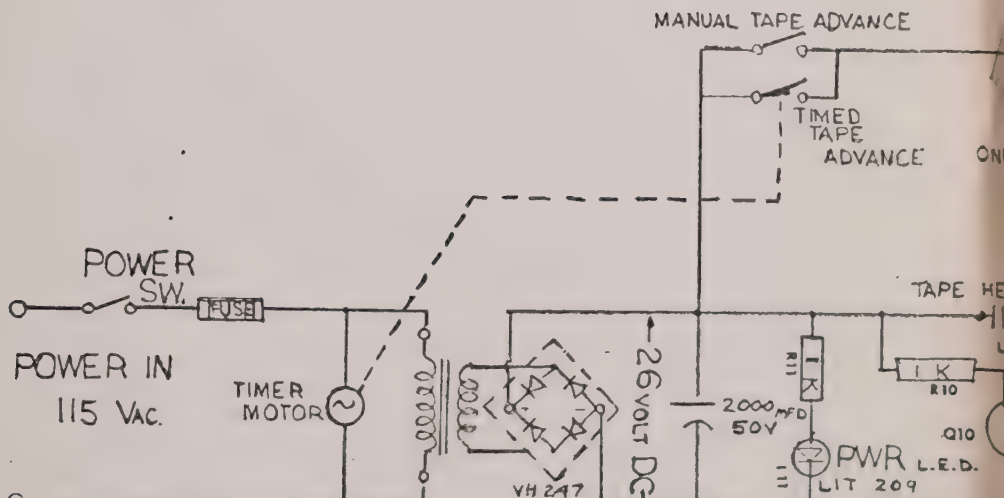
SYM	DATE	CHANGE	BY	SYM	DATE	CHANGE	BY
A				C			
B				D			

MATERIAL (MODIFICATION)
4-#8 FLAT WASHERS
1" 1978-3 THERMOTRON CAM

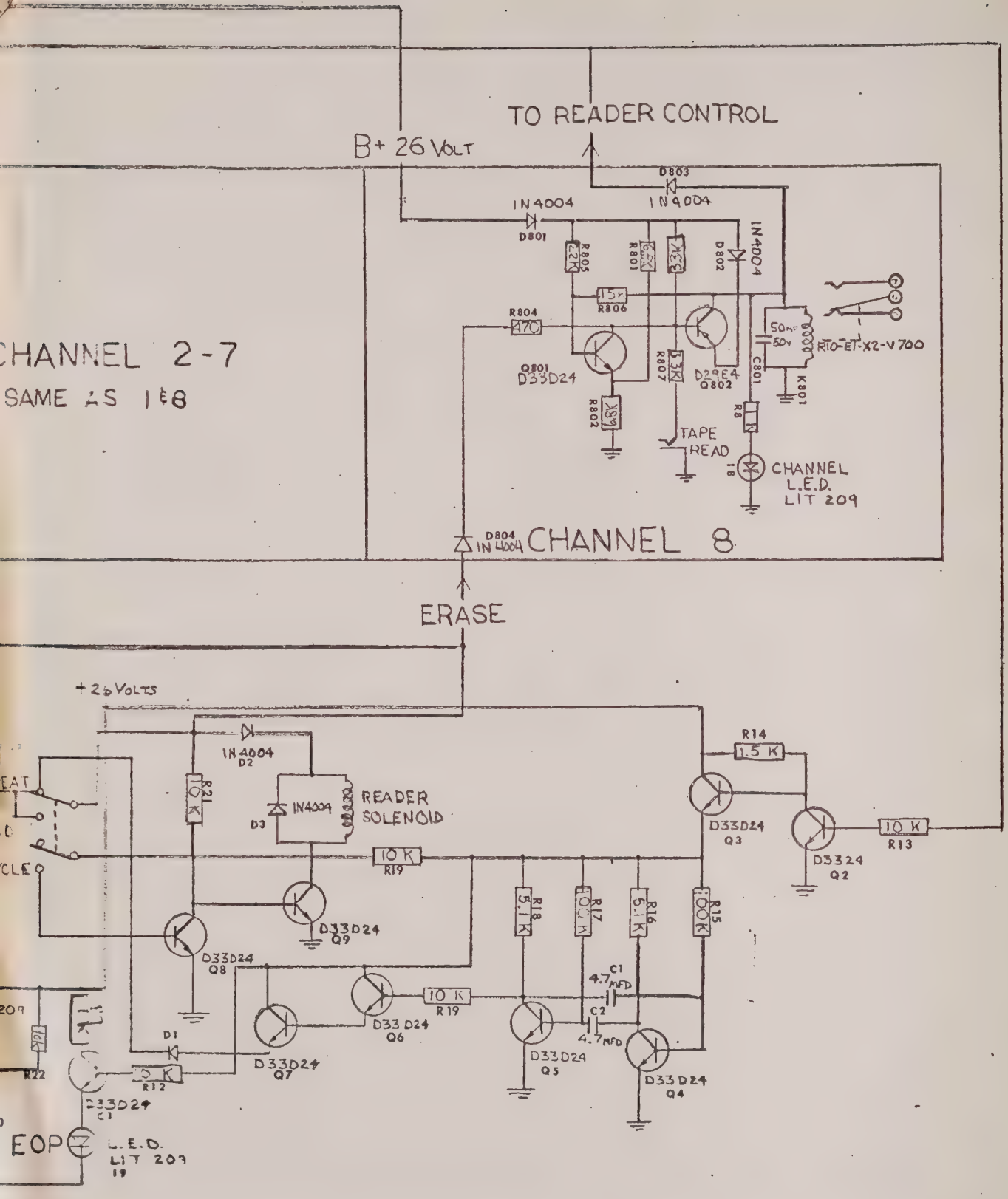
THERMOTRON CORP.
HOLLAND, MICHIGAN U.S.A.

DRAWN BY	DATE	SCALE	APPROV.	DESCRIPTION	FOR	DRAWING NO.	SIZE
							Z





THERMOTRON
CORPORATION
HOLLAND, MICHIGAN 49423



CHANGED	NO.	CHANGED	DATE	BY	CHK'D

TOLERANCE

SCALE

MATERIAL

FINISH

DRAWN BY R. HOSLEY DATE 4-30-13

CHECKED BY DATE

RELEASED BY DATE

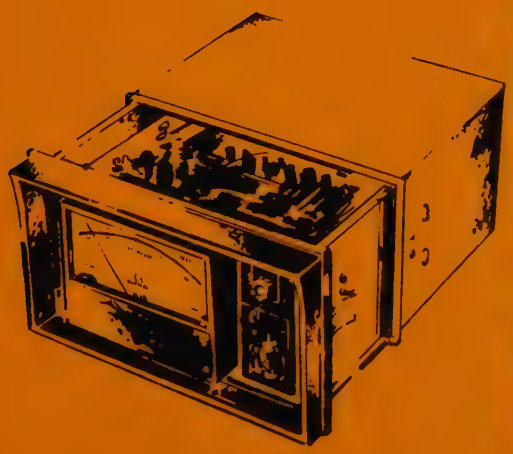
DESCRIPTION

P.C. BOARD WIRING SCHEMATIC FOR TAPE COMMAND

1061007

THERMOTRON

PRODUCTSAVER USER'S MANUAL



USER'S MANUAL

UM451011

PRODUCTSAVER
Model 012005

A Hi-Low Temperature Limit Control & Alarm System

April 1974

thermotron corporation
kollen park drive
holland, michigan 49423 u.s.a.
(616) 392-1491

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INTRODUCTION

The Productsaver goes back to 1970. Hundreds of these units are now in use around the world.

The instruments described in this booklet represent the third generation in the Productsaver family. The first generation was model 1992. The second generation included models 012001 and 012004.

One school of thought says 'if it's ok as is, don't change it'. But we feel that if we can make a thing even better, then we ought to do it. Each new generation is an improvement over the last. Some of the changes are our ideas. Some of them are the result of suggestions that we receive from users in the field.

Within each generation, there may be more than one model. The primary model number for the third generation of Productsavers is 012005. If your unit has a different model number, and that number is lower, it means that it belongs to a previous generation. This booklet isn't directly applicable to such instruments, but can be used as a guide. If your unit has a higher model number, its different number simply means that in some respect it's slightly different than model 012005. To find out exactly what the difference is, refer to the *Model Variations* section of this booklet. Except for those differences, this booklet is directly applicable to your instrument.

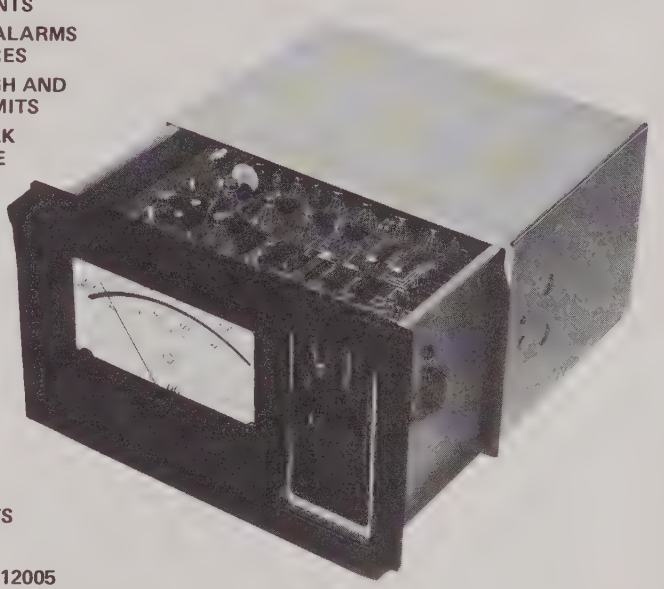
THERMOTRON

Productsaver™ MODEL 012005

HI-LOW TEMPERATURE LIMIT CONTROL & ALARM SYSTEM

- TYPICAL ¼% ACCURACY
- THERMOCOUPLE SENSOR
- LOW COST
- FULL–SCALE INDICATION OF TEMPERATURE AND SET POINTS
- VISUAL AND AUDIBLE ALARMS PLUS CONTACT CLOSURES
- ESTABLISHES BOTH HIGH AND LOW TEMPERATURE LIMITS
- POSITIVE SENSOR BREAK PROTECTION–FAILSAFE
- HIGH ELECTRICAL NOISE IMMUNITY
- FULLY SOLID STATE–22 IC's HIGHEST QUALITY COMPONENTS
- RUGGED DESIGN
- MANUAL OR AUTOMATIC RESET
- USER–SELECTABLE OPERATING CHARACTERISTICS
- TAMPER RESISTANT SET POINT ADJUSTMENTS

As a passive alarm unit, or a back-up limit controller, the Productsaver helps to protect your product, process and equipment from excessively high and low temperatures.



SPECIFICATIONS, MODEL 012005

INPUT: Thermocouple, type T; copper/constantan. Not affected by thermocouple resistances of up to 1000 Ohms.

RANGE: –125F to +375F with equivalent C scale (standard).

MEASURING/ALARM ACCURACY: ±¼% typical.

OUTPUTS:
Visual: Separate 'alarm' (ylw), 'high limit' (red) and 'low limit' (grn) warning lights.
Audible: Pulsing 2800 Hz, 70 db warning tone
Contacts: Separate 'alarm', 'high limit' and 'low limit' 1P2T contacts, rated 4A @ 115vac.

SENSOR BREAK/FAILSAFE PROTECTION: Special circuit provides full scale temperature indication, turns on 'alarm' light and turns off 'high' and 'low' limit contacts.

COLD JUNCTION COMPENSATION: Precision oven type stabilization.

ALARM SET POINTS: Screwdriver adjustable high resolution (±0.2%) potentiometers. Adjustable from front panel.

INDICATION: Six-inch meter displays temperature, and set point levels when 'high' and 'low' pushbuttons are depressed at front panel.

ALARM REPEATABILITY: ±0.1%

HYSTERESIS: Less than ±0.05%

OPERABLE AMBIENT RANGE: 32F to 131F (0C to +55C).

TEMPERATURE EFFECT: Less than ±0.01%/deg F (from 77F) over operating range.

MAXIMUM POWER REQUIREMENTS: 115vac 50/60 Hz, 10 volt-amperes maximum.

LINE VOLTAGE EFFECT: Less than ±0.03% for ±15% line voltage changes within operating range.

HOUSING: Panel mounting unsealed aluminum case, suitable for bench service.

CONNECTORS: Screw type barrier strips

DIMENSIONS: 5.8" (14.73cm) high, 9.6" (24.38cm) wide and 8.4" (21.34cm) deep. Protrudes 7.2" (18.29cm) behind mounting panels.

WEIGHT: 6.5 lbs (2.95kg).

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GENERAL DESCRIPTION

What is the Productsaver, and what does it do?

The Productsaver is 'a precision, electronic, thermocouple actuated, bi-directional temperature limit controller and alarm instrument'.

Simply put, the Productsaver is made for applications where it's very important that the temperature remains within prescribed limits. It's a temperature alarm unit. It's a temperature limit switch. It's a temperature limit controller. It can be used simply as a general purpose temperature controller. *It's a very versatile instrument.* It was made that way on purpose, so that one general design could serve in a variety of different applications.

The Productsaver was first designed for use with environmental and reliability test chambers. Such chambers are used widely in connection with the development and manufacture of military-aerospace electronic systems. In this field, the contents of the test chamber can easily be worth hundreds of thousands of dollars, and can take months to replace if accidentally subjected to extremely high or low temperatures. The Productsaver was developed in order to help assure that this couldn't happen. It was cheap insurance.

Since then, the applications for this instrument have widened considerably. The instrument now finds a home wherever out-of-tolerance temperature conditions can have adverse effects on the product, the equipment or the emotional stability of those in charge of the operation.

It's a good general purpose controller to keep around the lab. It makes a good spare controller to keep around the maintenance shop, as a temporary replacement for controllers on the line when such controllers must be removed for service or calibration.

The Productsaver is a precision instrument. It measures temperature very accurately. Its high and low trip points can be set with precision, and its switching action occurs precisely at the set points.

It's thermocouple sensor can be made of very light guage wire, which allows you to monitor the temperature at pinpoint locations if you wish. With a differant style of thermocouple, it is just as easy to monitor the temperature of a larger area. By connecting several thermocouples in parallel, it's simple to monitor the average temperature among several points, or throughout a large space.

Used as a temperature alarm, the Productsaver will alert you to out-of-tolerance conditions with alarms that you can see and hear. If you can't always be near the instrument you can wire up remote alarm devices to the relays on the back of it's case.

For fully automated equipment, it sometimes happens that 'human intervention' isn't immediately possible. During the graveyard shift, for instance, there might not be anybody around to notice the alarm. It might take them too long to get to the site to correct the trouble or stop the process. In these situations, the control lines of the heating and cooling equipment can be wired through the Productsaver's contacts. In case a run-away condition occurs it will then stop the equipment automatically, and hold it off until someone is able to attend to the problem. In such applications, it's contacts can also be used to instigate an orderly shut-down process by a computer or shut-down sequencer.

If shut-down/lock-out action is not particularly appropriate, you can switch the Productsaver to *automatic reset* operation in a matter of seconds. When this is done, it will stop the equipment when the temperature strays outside of, your prescribed limits. But if the temperature comes back within the limits, it will then restart the equipment automatically. Used in this way, the Productsaver makes a good back-up controller for use in connection with process control computer systems. If something gets scrambled up in the computer system, the Productsaver will automatically take over until the computer problem can be corrected.

The Productsaver can also be used to back up other types of controllers, automatically keeping the situation in hand in case the primary controller falters, which could mean the difference between an unscheduled shut-down and keeping production rolling along.

The Productsaver's spec sheet is reprinted here. From this you get the formal vital statistics of the instrument. *These specs are realistic and there is generally no need to 'derate' them or add fudge factors.* For instance, we say that the typical accuracy of these units is ±¼%. This means that when you calibrate these instruments, you'll find that errors larger than 1¼ deg F are rarely encountered. We guarantee 1% accuracy at calibration; we'll fix any unit that won't perform accordingly.

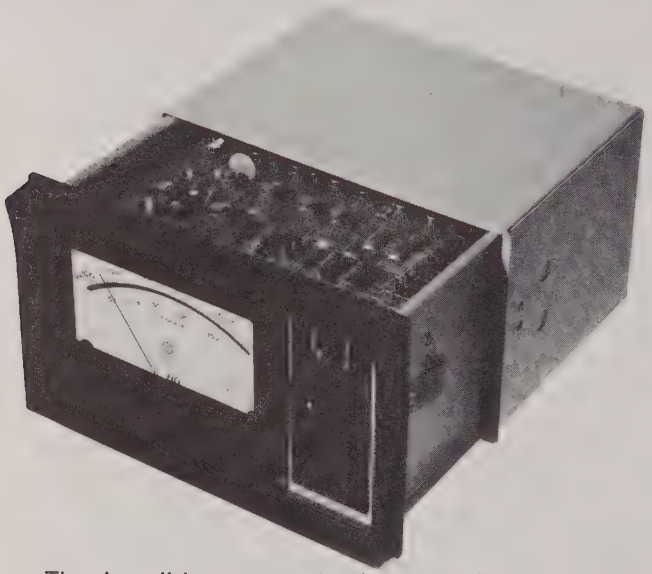
INFORMATION FOR USERS

The better you know the Productsaver, the more useful it will be to you. If you want to get the most out of this section, with the least amount of effort, hook up one of your units at your desk or work station, using a power cord and a short thermocouple. This will give you some *hands-on* experience, and you'll be able to see exactly what we're talking about in the following paragraphs.

WARNING

If you're going to do this, be careful to recognize the possibility of **ELECTRICAL SHOCK.** The voltage used in the Productsaver circuitry itself is generally low enough to constitute no serious hazard to you. But the line voltage connected to the unit (115vac) is potentially quite dangerous. Keep your hands well away from that connection, on the back of the unit!

Looking at the front of the Productsaver, you see a temperature meter, three lights, a small 'beeper' and two screwdriver adjustments.



The three lights are warning indicators. The red light (right side) will come on whenever the temperature goes above the high set point. To its left is a green light, which comes on whenever the temperature goes below the low limit. Centered above these two lights is the yellow light, which comes on (flashes) whenever the temperature strays outside of your preset limits.

The beeper generates a high-pitched pulsing sound whenever the temperature goes outside the limits.

The lights are more than just lights. They're also push-button switches. When you push the red light, the meter indication changes. It's now reading the high limit set point. You can set the high limit by holding the red button down and turning the screwdriver adjustment just below it until the meter reads the desired temperature.

To set the low limit, you do the same thing. Push the *green* button and turn it's associated screwdriver adjustment until you get the reading that you want.

When you release the pushbuttons, the meter will return to it's task of indicating the actual temperature.

The pushbuttons do more than this too. Suppose that you heat the thermocouple with a lighted match. The meter reading will move upscale, way past your high limit setting. When this happens, the red light will come on, the yellow light will flash on and off, and the beeper will pulse at a rate of about one or two pulses per second . . . all designed to attract your attention.

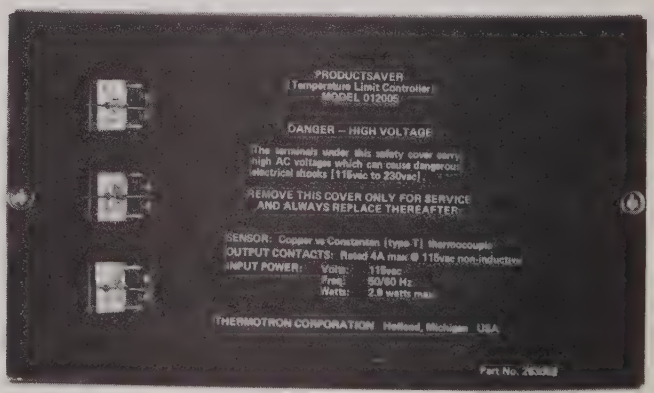
When you take the match away, the temperature will return to normal, *but the alarms will remain activated.* This is because the instrument is set for *manual reset*, and the alarms lock on once they are tripped.

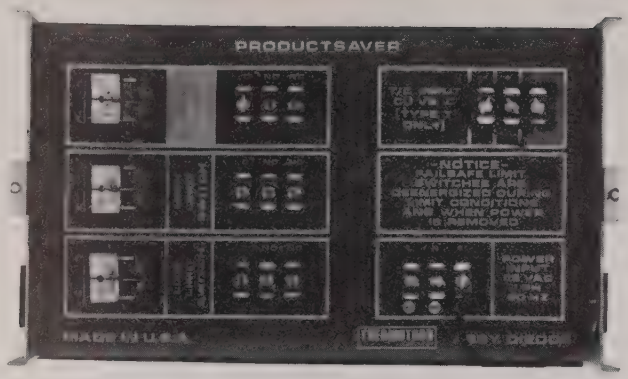
To quiet things down, push the yellow button. This silences the beeper. Also, the yellow light will stop flashing and stay on all the time . . . a signal that someone may already have the situation under control.

Now, to get back to normal, push the red light. When you do, it'll go out, and so will the yellow light. You're now back in business, with the Productsaver on guard, watching for out-of-limits temperature conditions. The operation of the green low limit channel is the same, except that it will be tripped only when the temperature goes too low.

We've provided a mirror behind the meter scale. This feature helps you take accurate readings. Looking at the meter, you'll see it's pointer and the pointer's reflection in the mirror. Move your head slightly, until you can see just one pointer. You're now looking head-on at the meter, and can take an accurate reading. The small error that otherwise results from reading the meter at an angle is called *parallax*, so this is called an *anti-parallax* scale.

Looking at the back of the Productsaver, you'll see three relays. Remove the safety cover. Now you can see that these three relays are color-coded red, green and yellow, just like the lights in front. These relays work with those lights.





When the red light is *off*, the red relay will be *on*, and vice versa. The yellow relay does not pulse (although you can wire it to do that); when the yellow light is off this relay will be on. When the yellow light is flashing or on steadily, the yellow relay will be off. As you can see, these relays are wired for 'failsafe' operation. They are open, or off, when an alarm occurs. Thus, if they fail to operate, or if Productsaver power is lost, their contacts will remain in the 'alarm' position. This is important if you're depending upon these relays to sound remote alarms or to shut down remote equipment.

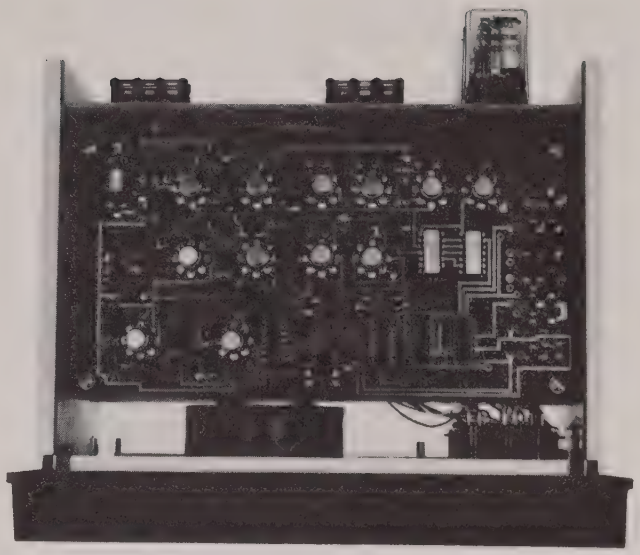
The back panel also has the terminals at which you'll connect your thermocouple and line power.

While you have the back loose, slide the case open. In the front left corner of the top circuit board you'll notice two small screwdriver switches. These switches are color-coded red and green, since they change the operation of the high and low limit channels.

Before we ship the instrument, we set these switches at position *2*. In this position, both limit channels must be reset manually once the alarms have been tripped. But you'll notice that the alarms automatically reset themselves when you first turn on the instrument. Suppose that you have several Productsavers operating within a given system. Every time you apply power to the system you must also reset all of these Productsavers. This can be inconvenient and bothersome.

For this reason, the instrument includes a special circuit that resets the alarms for you when power is applied. If you would rather reset them manually, or if you want the Productsaver to detect power failures, set these switches at *position 3*. If power is momentarily interrupted during an electrical storm (or for any other reason) the instrument will come back on in the alarm mode when the power returns, with the beeper automatically silenced. Position 4 of these switches is jumpered to position 3, and provides the same response.

If you want automatic reset *all the time,* put the switches in *position 1.* To use the instrument as a controller set both switches to this position.



You can, if you wish, set the red and green limit channels for separate operating modes, since there is a separate switch for each channel. The yellow channel always operates with the red and green channels. So if you have automatic reset on the green channel, the yellow channel will also reset automatically with the green light. If you set the red channel for manual reset, then the yellow channel will be reset manually with the red light.

RESET SWITCH SETTINGS

Set Switch at:	To Provide:
1	Automatic Reset
2	Manual Reset/Automatic Start Up
3 [or 4]	Manual Reset/Power Failure Detection

INSTALLATION & WIRING

Mounting

The Productsaver is designed especially for panel mounting. All necessary mounting hardware is provided with the unit. All you need is the panel.

You'll want to mount the unit at a spot where it's audible and visual alarms will be easily noticed. Be sure to provide yourself with convenient access to the front panel, and remember to provide maintenance people with easy access to the back of it.

Like any electronic instrument, vibration isn't going to do it much good. If you're going to mount it on a machine you might consider using a vibration-damped mounting panel.

You'll be connecting wires to the back of the unit, so you'll want to mount it at a location which is not too hard to get to with these wires.

After it's installed, the back of the Productsaver will protrude about 7½" behind the mounting panel, so you need at least that much clear space behind the panel.

When you've chosen the mounting location, cut a rectangular hole in the panel. Make this opening about 9 1/8" wide by 5 3/16" high.

Then slip the Productsaver through this hole, from the front side. Now find the two mounting brackets and go around to the back side of the panel.

Notice the two knock-outs on either side of the instrument's case. Orient the mounting brackets so that their tabs touch these two knock-outs, with the screw pointing towards the mounting panel.

Now push the brackets hard against the case to push in the knock-outs, then pull them back slightly to engage their tabs. Tighten the screws in the mounting brackets until they're snug against the panel . . . no need to reef them down. Then tighten the locking nut on the screw aginst the mounting bracket. That's all there is to it!

electrical noise

If you have any arcing, sparking contacts in the area, you might first want to plug in the Productsaver at the proposed mounting location to see how it reacts to all that *electrical noise.*

The Productsaver has a very high level of noise immunity, so if you haven't had much trouble with other instruments, you probably won't have noise problems with this one. If you do run into noise problems (indicator wavers, relays chatter, false alarms), the thing to do is track down the source of the noise. Then either fix that device or add noise suppressors at that point, not at the Productsaver.

If the Productsaver is affected, you've got a real noise problem. It will be almost impossible to make this unit, or any other electronic instrument, immune to it. That's the nature of noise. Stop the noise *at it's source!*

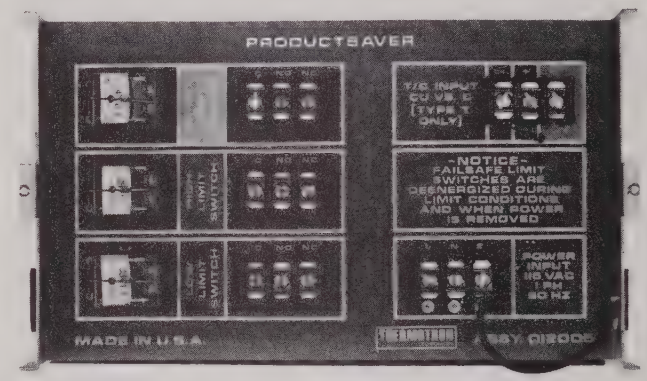
Wiring

Take the safety cover off the back of the unit and have a look at its terminal blocks.

thermocouple connection

In the upper right corner of the back board is the sensor terminal block. This is where you connect the thermocouple wires.

When you connect the thermocouple, you have to be sure to get the polarity right. One of the wires is [+] and one is [–]. We've color-coded these terminals and marked them [+] and [–]. Don't connect anything to the terminal marked [ck]; that's for checking the reference junction.



Thermocouple wire is also color-coded. This helps you make sure that you have the right type of wire and the right polarity:

THERMOCOUPLE COLOR CODES

TYPE	*	+ wire	– wire
copper/constantan	T	blue	red
iron/constantan	J	white	red
chromel/constantan	E	purple	red
chromel/alumel	K	yellow	red

(*) ANSI/ISA designation [type code]

So far as the Productsaver is concerned, the size of your thermocouple wire isn't important . . . length or gauge.

If there's a long distance between these terminals and the thermocouple itself, you might have to use some *thermocouple extension wire* to complete the run. Regular wire won't do. You have to use the same type of wire as the sensor is made of, and it will have the same color code. It's not particularly important that the extension wire be the same gauge or wire style as the sensor.

power connection

In the lower right corner are the power input terminals:

[L] means *Line*
[N] means *Neutral*
[E] means *Earth*

The power required is 115vac, 50 to 60 cycles (Hz), at a load of not more than about 87 milliamps (10 volt-amps). AWG 16 or 14 wire is recommended:

—connect your hot line (red or black wire) to L.
—connect your neutral line (white) to N.
—connect your ground line (green) to E.

Your ac supply should be equipped with a fuse or circuit breaker rated at not more than 15 amps. The ground wire should be connected to a good earth ground, like a water pipe.

That's all there is to the power connection. Inspect the job closely prior to applying power to assure that there are no shorts, and that the connections are correct.

WARNING

115vac is a dangerous potential! Never work on the back of the Productsaver with power applied. With power on, the danger of ELECTRICAL SHOCK and indirect physical harm is very real, and should not be taken lightly.

output relay connections

On the left side of the terminal board are the output relays and their terminal blocks. These, too, are color-coded and in this case the colors are chosen to match the colors of the alarm indicators on the front of the unit. In this way, it is easy to tell which relay is which:

RED: High Limit Relay
GREEN: Low Limit Relay
YELLOW: Operates with either limit

These relays will be energised when everything is OK. They will be de-energised when something goes wrong.

Take a look at the terminal blocks. Each relay has three terminals marked *C, N.O.* and *N.C.* This means:

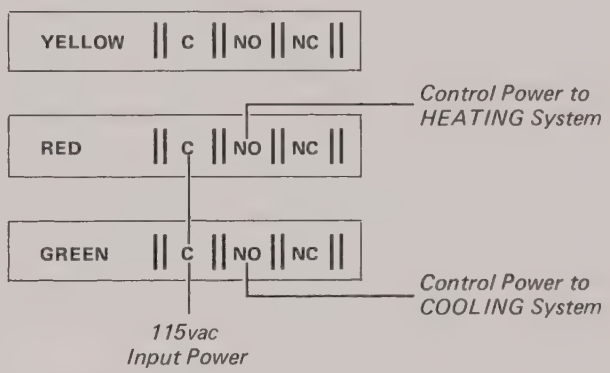
C: Common side of contact
NO: Normally-open side of contact
NC: Normally-closed side of contact

These markings apply to the relay itself, *not to alarm conditions.* In other words, when the Productsaver is off (no power applied to it), the C terminal is connected to the N.C. terminal by the relay.

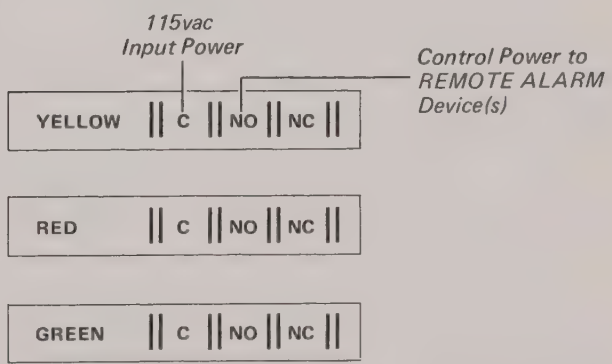
The relay contacts are rated 5A@28vdc or 4A@115vac. So if you connect anything to these contacts, these current limits must not be exceeded. If they are, the life of the relays might be greatly reduced, and the hazard of the relay being welded in the closed position will be high.

Inductive loads, such as transformers and motors, can cause heavy arcing at the relay contacts. Have a look at the contacts as they operate after you have connected your load. If they arc very much when the load is switched, try connecting a 0.1mfd 1500v disc capacitor across the load, and as close to the load as possible. This will help to lengthen the life of the relays' contacts.

To get an idea how to hook up your thing, here are some examples of typical applications:



example 1: To interrupt heating at the high limit and cooling at the low limit. Acts as a limit switch with manual reset, or a limit controller with automatic reset.



example 2: Remote high-low alarm devices may be connected as shown here. For high-only or low-only operation, use the same connection at the red or green relays.

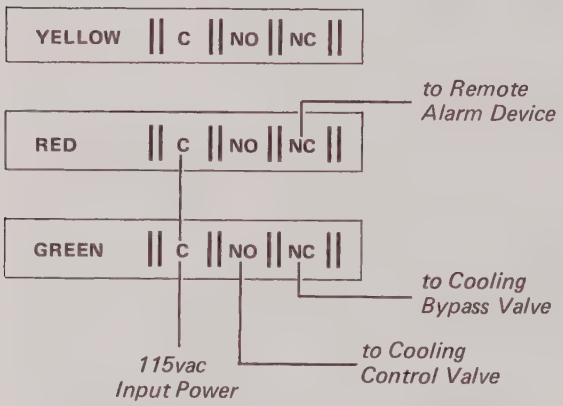
OUTPUT VARIATIONS

You can change the operating characteristics of some of the outputs to suit your particular application.

Red Light, Green Light & 'Beeper'

Look at 'example 1', above. If you're using the instrument as a limit switch you'll be satisfied with things as they are. If you're using it as a *back-up limit controller*, you might also find that the operation of the high and low temperature lights is as you like it; *off when the temperature is within limits.*

But suppose that you want to use the unit as a cooling controller with an overtemperature alarm. To do this, you'd hook up the outputs like this:

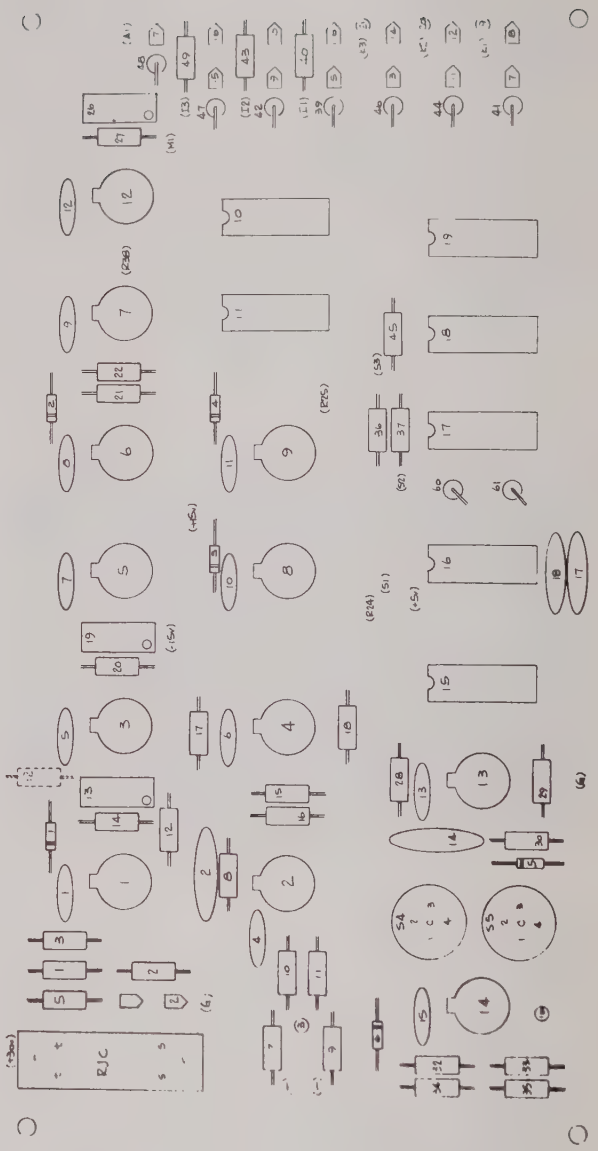


example 3: Cooling controller with an over-temperature alarm. Refer to text for further details.

Next, you'd set the *green switch* inside the unit for automatic reset,—*position 1.*

Now you're in business, except that the green light will come on when the cooling line is switched off, and vice versa. If you want the green light to indicate that the instrument is calling for cooling, you can have it that way.

In the lower right corner of the schematic diagram, find resistor R42. In order to make the green light operate with the green relay, change the connection of R42 from point 'k' to point 'm'. You'll need a soldering iron to do this.



You can find the location of all of the components on the component outline drawings. R42 is mounted vertically, just to the right of IC10, pin 10. It's the *fifth* resistor in the row, counting from the front edge of the main circuit board. Desolder the wire-end of this resistor, rotate it 45-degrees counterclockwise, and resolder it in the hole provided at that point.

The red light may also be changed in this manner, if you wish to reverse it's operation.

To change the operation of the red light, you would change the connection of R39 as described above. Resistor R39 is located just east-southeast of

IC10, pin 8. This is resistor number four, counting from the front of the circuit board. Desolder its wire-end, rotate 45-degrees counterclockwise, and resolder at the hole provided.

. . . this you would do whenever you intend to use the Productsaver as a heating controller.

In 'example 3', when the cooling demand is satisfied, the beeper will sound. You can change this with a quick wiring change on the main circuit board.

Locate resistor R61 on the main circuit board. This resistor is one of the two vertically mounted resistors found between IC16 and IC17. It's the one which is closest to the front of the board.

Remove this resistor from the circuit. Cut a ¼" length of wire off R61 and use it to connect pin 5 of IC17 to pins 3 and 4, which are already shorted together.

The yellow alarm channel, which includes the beeper, will now operate *only when the high limit is tripped.*

For the case of a heating controller with an undertemperature alarm, you'd want the yellow channel to operate only with the low limit channel. To achieve this, follow the above procedure, except *remove R60 instead of R61.*

Yellow Alarm Circuit

In the above few paragraphs, we discussed how to disconnect the yellow alarm channel from the red or green alarm channels when the Productsaver is to be used as a temperature controller. You can also change the reset mode of the yellow channel.

At the factory, we wire the yellow alarm circuit so that it is operated by the red and green alarm circuits. Therefore if the red and green alarms are set for manual reset, the yellow circuit won't reset until you push the reset buttons.

You can get automatic reset on the yellow alarm by changing the connections of resistors R60 and R61. Again, these are the two vertically mounted resistors found between IC16 and IC17. The one closest to the front edge of the board is R61.

To provide automatic reset on the yellow alarm channel simply disconnect the wire-end of these resistors, rotate them 90-degrees clockwise, and resolder them in the holes found at that location. R60 is the red side and R61 is the green side. If you want automatic reset in conjunction with low alarms only, then change only R61's connection, etc.

Yellow Relay Operation

We wire up the yellow relay, K3, so that it's closed during normal operation and opens when the temperature goes out of limits. If you're hooking up a remote alarm, you might want it to pulse. Your remote alarm will work just like the beeper if you change the connection of resistor R46.

R46 is the *third resistor* in the row of vertically mounted resistors, counting from the front edge of the main circuit board. To connect for pulse operation of K3, rotate it's wire-end 90-degrees counterclockwise, and resolder at the hole provided.

If you want the remote alarm to also signal loss of power at the Productsaver, reconnect the wire-end of R46 at the hole between it and R44, then change the connection shown in 'example 2' from the N.O. terminal to the N.C. terminal.

CALIBRATION & ALIGNMENT

Unless you have a formal calibration program of your own, it's "good practice" to check the calibration and alignment of this type of instrument at least once every six months.

Equipment Required

In order to do this, you'll need the things listed below:

1. a portable potentiometer: this is an instrument especially designed to measure thermocouple emf's, and to produce test outputs which simulate thermocouple signals. Most portables have millivolt scales. Some have scales which are calibrated directly in degrees. If yours has a temperature scale, it probably includes *second-junction compensation.* Be sure that the calibration of its temperature scale and compensator matches the type of thermocouple used by the Productsaver.
2. if your portable doesn't have a temperature scale which suits the Productsaver, but does have a millivolt scale, then you'll need some crushed ice and a large-mouthed thermos bottle.
3. a digital voltmeter; capable of reading +15.0vdc and +5.00vdc. The accuracy of this meter should be 0.1%. Don't use a regular analog-type VOM or VTVM, since these instruments aren't usually very accurate.
4. three to six feet of *thermocouple extension wire* of the same type used by the Productsaver. **This is a must.** Don't use any other type of wire.
5. two common screwdrivers . . . one 6" size and one pocket-sized.

Getting Set Up

If your portable is a compensated type, you may hook one end of your thermocouple extension wire directly to it's terminals. Be sure to observe polarity. Red is negative.

If your portable isn't compensated, then hook only the [+] side of your extension wire to it. Now take another piece of [+] type wire *(it's got to be the same kind of wire that you've hooked to the [+] terminal),* and hook it to the [–] terminal of the portable.

Now splice the loose end of this wire to the [–] end of your extension wire. Stick this junction into your ice bath. To get this right, you need a *melting crushed-ice* situation. Add a little water, just enough to saturate the ice. You also ought to coil up about six inches of the wire near your spliced junction before you plunge it into the ice. You should submerge at least six inches of the wire, but make sure that your junction is not touching the rest of the wire, or the sides of the container.

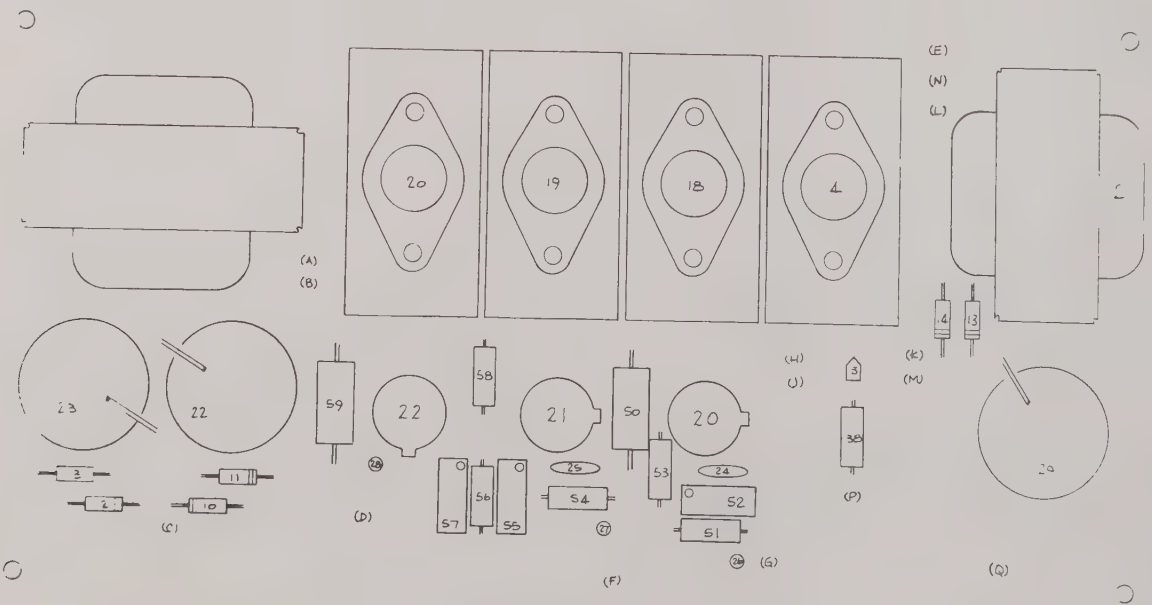
You've now made a *reference junction*. Stir it around now and then, and it's temperature will be exactly +32F, the temperature of melting ice; very accurate.

WARNING

You'll be working inside of the Productsaver with power on. There's a potential of 115vac, 50/60 Hz on the terminal and power supply circuit boards.

Make sure that you know what you're touching! If you come into contact with this potential, you can be seriously injured.

Also, solid state circuitry can be easily zapped. If you accidentally short out something, permanent damage might result to the unit. So be careful with screwdrivers, probes and test clips.



Remove the safety cover from the back of the Productsaver, and disconnect the thermocouple sensor's leadwire. Tuck this wire to one side to make sure that it doesn't come into contact with the 115vac connections in this area.

Hook up the loose end of your thermocouple extension wire to the thermocouple input terminals. Remember; *red is negative [–].*

You'll want your portable at the front of the Productsaver, since that's where you'll be working. If your wire isn't long enough to reach around to the front, push the case open slightly and push the wire through to the front along the side, between the chassis and the cover.

Now, if you're going to set your portable in terms of *millivolts*, find the *'emf vs temperature'* tables for the type of thermocouple that you're using with the Productsaver. In what follows, we're going to give you the millivolt figures for a *copper vs constantan* thermocouple, *type T.* If yours are different, write them in the spaces provided so that you won't have to look them up next time. Our standard range is –125F to +375F.

Zero and standardize your portable, then set its output to a value that drives the Productsaver's indicator to about midscale (+158F = +2.908mV)(= mV).

Procedure

1. Now connect the [–] lead of your DVM to the lead of capacitor C27, underneath on the power supply board.
2. Connect the [+] DVM lead to the junction of resistor R54 and capacitor C27. Now turn potentiometer R55 until the DVM reads exactly +15.00vdc.
3. Connect the [+] DVM lead to pin 8 of IC22 *(very carefully)*, and adjust R57 for a reading of exactly –15.00vdc.
4. Connect the [+] DVM lead to the junction of R51 and C26, then adjust R52 for a reading of +5.00vdc.

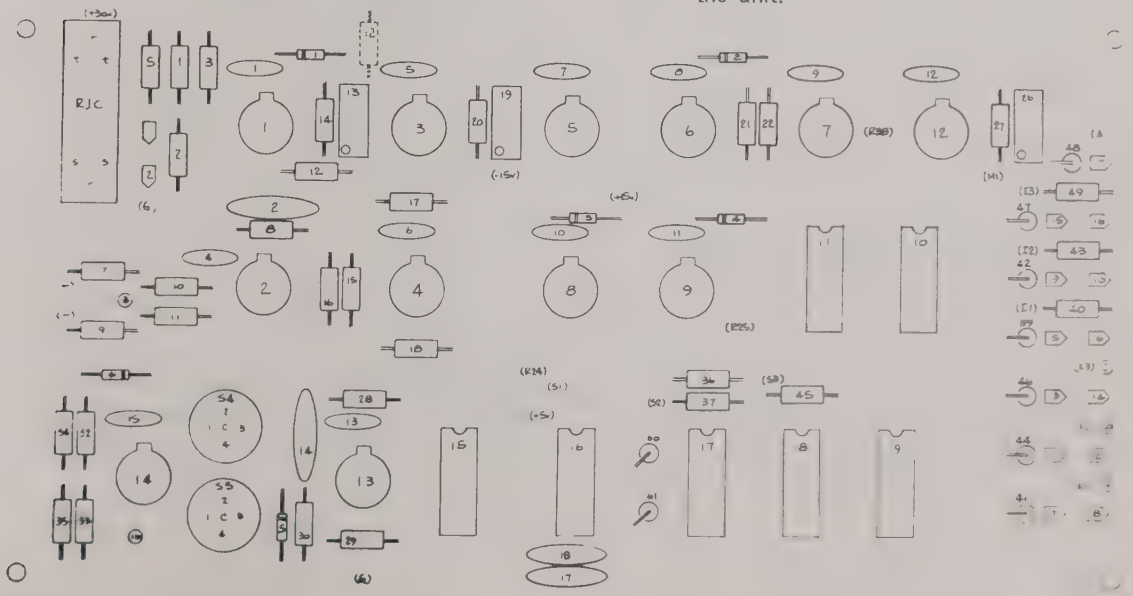
So much for the power supply. Leave the [–] DVM lead where it is, and connect it's [+] lead to IC5, pin 8, on the main circuit board, on the top side of the unit.

5. Now set your portable to the temperature at the left end of the Productsaver's scale: (–125F = –3.006mV)(= mV).
6. The DVM indication should now be 0.000vdc. If not, adjust R13 until you get this reading.
7. Now look at the Productsaver's meter. Its pointer ought to be right over the left end scale mark, exactly. If not, adjust the mechanical zero adjustment on the front of the meter to provide that indication.
8. That does it for zero. Now set your portable to the temperature at the high end of the Productsaver's range (+375F = +8.787mV)(= mV)
9. The DVM should now read exactly +5.00vdc. If not, you'll have to adjust R19 to get it.
10. Now have another look at the meter. If the pointer isn't splitting the right end scale mark, adjust R26 until it does.

That's about it for alignment and calibration. If you want to recheck the calibration accuracy at this time, go ahead:

(–125F = –3.006mV)(= mV)
(0F = 0.647mV)(= mV)
(+100F = +1.518mV)(= mV)
(+200F = +3.967mV)(= mV)
(+300F = +6.647mV)(= mV)
(+375F = +8.787mV)(= mV)

When you've finished, disconnect the DVM and close the case. Disconnect your extension wire, and *don't forget to hook the sensor back up.* Also be sure to replace the safety cover on the back of the unit.



MINIMUM PERFORMANCE CHECKS

In this procedure we'll go through the Productsaver step by step, from front to back, to make sure that each part is working properly.

In this booklet, there is no troubleshooting procedure, as such. The reason for that is that the familiar 'symptom—probable defect' lists are usually not very helpful. Failures are usually very random. If there was a neat pattern of 'usual failures', we'd redesign the product and get rid of such weaknesses.

If you have troubles, or suspect troubles, go through this procedure with the unit in question. It doesn't take very long, and somewhere along the line you'll probably find the defect, if there is one, glaring at you. You'll at least be able to isolate it to a particular section of the circuitry. Then too once you've made it through this procedure, you'll be able to have a high level of confidence that the unit is 100% 'go'.

Don't try to guess what the trouble is, and don't jump to conclusions about faulty components.Testing a component part by replacing it is not good troubleshooting practice. It wastes a lot of parts and a lot of time. If you suspect that a certain part is bad, see if you can think up a few ways to prove it, without disconnecting it from the circuit. If you can't prove it's bad, try to prove that it's good.

In connection with this, remember that in the *Circuit Analysis* section of this booklet, we've provided a run-down on each and every circuit, and each and every part used in the circuit. If you don't know exactly how a certain circuit is supposed to work, it'll take you only a few minutes to find out.

You'll be interested to know that this procedure is used at the factory to qualify Productsavers for shipment. So, once you get through this, your unit will be in 'like new' condition.

Equipment Required

In addition to common electronic tools, you'll need the following items in order to do this exercise:

Portable Potentiometer
Variac
Digital Voltmeter
Oscilloscope
Decade Resistor

** if the Portable isn't compensated, you'll also need a thermos bottle and some crushed ice.*

General Set Up

To begin, refer to the *Calibration and Alignment* section and connect the portable as directed there. Set it to drive the indicator pointer to about midscale:
(+158F = +2.908mV)(= mV)

Connect the variac to the Productsaver, and set it to provide 115vac. The variac dial might not be very accurate, so you should measure this. If you want to, loosen the knob on the variac and reset it so that it reads right.

Set the high and low temperature limits to about 75% and 25%, respectively:

High Limit: (+270F)( )
Low Limit: (+ 30F)( )

Power Supply Checks & Adjustments

The power supply system produces six dc potentials; ±30vdc unregulated, +12vdc unregulated, ±15vdc regulated and +5vdc regulated. The instrument will never work better than its power supplies. Checks include:

Unregulated Voltage Levels
Regulated Voltage Levels
Line Regulation
Nominal Load, Load Regulation and Limit
Oscillation, noise and transient response

All work will be done on the power supply circuit board on the underside of the unit.

unregulated voltage levels

Connect the DVM [+] lead to point C, and it's [–] lead to the can of capacitor C22. Set the variac at 115vac. The DVM should indicate +29vdc, ±4vdc. Note: This level will fluctuate with the operation of the rjc circuit, at about one pulse per second. When the rjc circuit switches on, this level will drop to about +24vdc for a moment. When the rjc circuit switches off, it will recover to +29vdc, ±4vdc.

Connect the DVM [+] lead to IC22, pin 5. With the line voltage set at 115vac, the DVM indication should be –29vdc ±4vdc.

Connect the DVM [+] lead to point K or point M. The indication should be +12vdc, ±4vdc.

regulated voltage levels

Connect the DVM [+] lead to point F. The correct indication is +15.00vdc exactly. Adjust R55 to get it.

Move the DVM [+] lead to point D, and read exactly –15.00vdc. If not, adjust R57.

Now connect the DVM [+] lead to point G. The correct reading is +5.00vdc exactly. Adjust R52 as necessary to produce this reading.

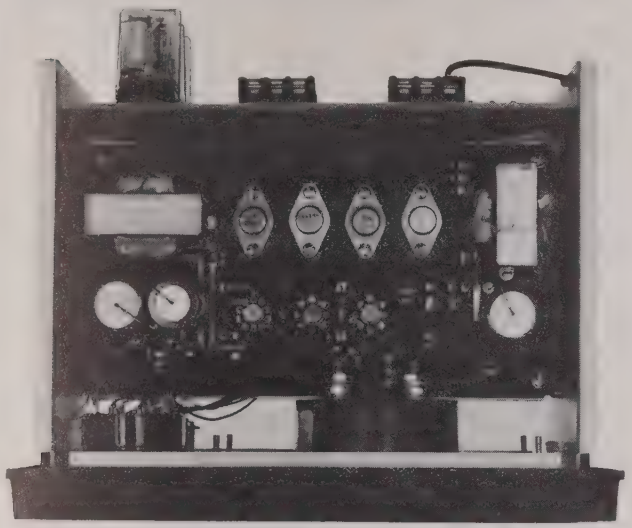
line regulation

The three regulated supplies are now set for +15vdc, –15vdc and +5vdc. To check each regulator for its ability to reject line voltage variations, recheck each one with the variac set for 90vac and 130vac. The maximum allowable variation is ±0.15%.

Point F: +14.98v to +15.02v
Point D: −14.98v to −15.02v
Point G: + 4.99v to + 5.01v

nominal load, load regulation & current limit

We'll now check the ability of the regulator circuits to compensate for load current variations, their nominal load current and their current limit settings.



Connect the DVM across resistor R50. The DVM indication will be about 200mV, ±20mV. By Ohm's Law, you can calculate that the nominal load current of the positive regulators (+5v and +15v) is about 67mA (200mV÷3 Ohms).

Connect the decade resistor between point G and ground (C22 can). Set the decade box to the value that produces a DVM indication of 300mV ±10mV (about 133 Ohms). The total positive load current is now (300mV÷3 Ohms) about 100mA.

Temporarily reconnect the DVM to recheck the regulated voltage levels:

[−] DVM lead to C22 can
[+] DVM lead to point G: Read + 4.99v to + 5.01v
[+] DVM lead to point F: Read +14.98v to +15.02v

Now reconnect the DVM across R50.

Set the resistance decades to zero. This shorts out the positive supplies. The DVM indication will now be 375mV ±25mV. This is the current limit for the positive voltage regulators; (375mV÷3 Ohms) 125mA.

Disconnect the decade box, and then reconnect the DVM as you did just above to check the positive supply voltages. They must instantly recover to within the limits given.

Now we'll check out the negative regulator. The procedure is about the same.

Connect the DVM across resistor R59. The nominal indication should be 100mV ±20mV. The nominal load current is therefore about (100mV÷5.1 Ohms) 20mA.

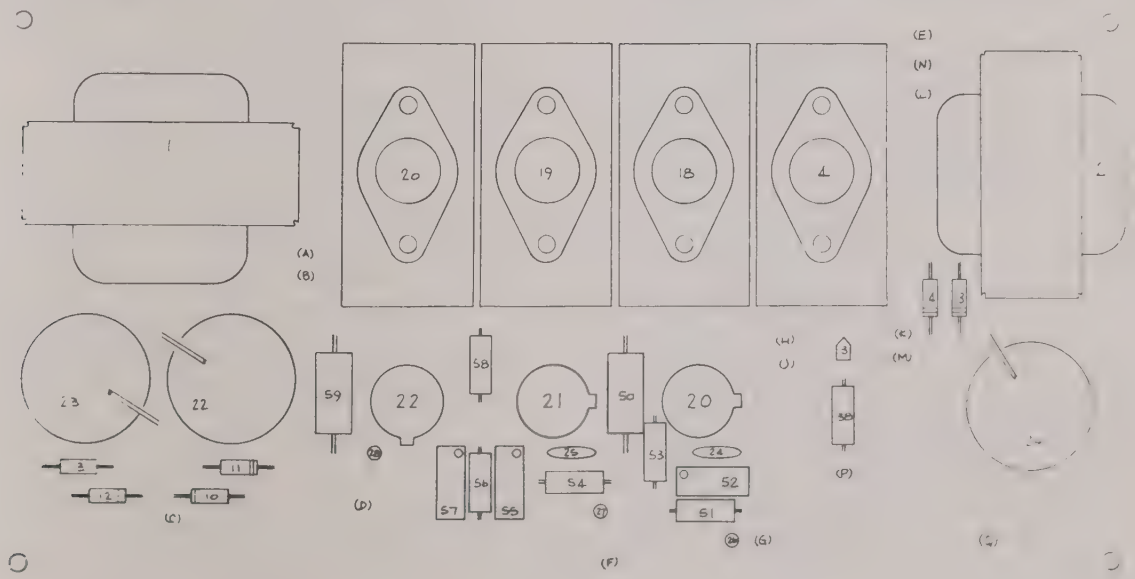
Connect the decade box between point D and ground. You can pick up ground at the case of C22. Set the decades to produce a DVM indication of 510mV ±10mV. The setting will be about 187 Ohms. With this DVM indication the negative load current is about 100mA (510÷5.1).

Connect the DVM to check the −15v level:

[−] DVM lead to C22 can
[+] DVM lead to point D: Read −14.98v to −15.02v

Reconnect the DVM across R59.

Now set the decades all to zero to short out the −15v



supply. The DVM indication will now be about 640mV ±50mV. The short circuit current is therefore about 125mA (640mV÷5.1 Ohms).

Disconnect the decade box and recheck the –15v level, as just done above, to see that it recovers properly.

oscillation, noise & transient response

Set up your oscilloscope for a vertical sensitivity of about 10mV/cm, and a sweep speed of about 1cm/sec; or as close as you can get to these settings – not critical.

Connect the scope's [–] lead to ground (C22 case). Then alternately connect its [+] lead to points D, F and G.

At each of these points, the combined amplitude of any oscillation, noise and transient spikes shouldn't be more than 20mV peak-to-peak.

SPECIAL NOTE

If you observe excessive high frequency oscillation, usually 1MHz to 5MHz, replace capacitor C26, C27 or C28. The supplies interact somewhat when this trouble occurs. To tell which one is bad, heat up each capacitor connection with a soldering iron and watch for the scope presentation to change. This will usually expose the one that's bad. Otherwise, change the one that's connected to the worst point first.

This type of oscillation occurs as a natural interaction between the integrated regulator circuits and the booster transistors; the function of the above capacitors is to prevent this interaction.

On rare occasions, a similar type of oscillation can be produced by defects in the circuitry on the main circuit board. If heating the above referenced capacitors produces no significant change, connect the scope to the power supply lines on the main board to see if the amplitude of the oscillation is greater on that board. If it is, then the problem is somewhere on this board, and it will be very hard to isolate since the high frequency energy propagates so readily throughout the circuitry. Generally, suspect IC13 and IC14, and their interface with the digital IC's. IC14 can be eliminated as a possible cause by switching S4 and S5 to position 1. IC13 is most suspect if the oscillation 'pulses' at a rate of about 1Hz. A bad compensation capacitor at any other IC can also cause this same problem. This can be checked out by connecting +15v to pin 3 of each eight-pin IC while observing the scope.

This problem doesn't happen very frequently, but is very difficult to troubleshoot when it does occur; that's why we've given it a special mention here.

Reference Junction Control Circuit

The temperature measuring ability of the instrument depends on the proper operation of the RJC circuit. To make sure that this circuit is working right, we'll check:

rj temperature
RJC stability

rj temperature

Go to the input terminals on the back of the case. The [+] lead from your portable is connected to the [+] terminal. Disconnect it, then reconnect it at the 'ck' terminal.

Using your portable in its measuring mode, measure the reference junction temperature. It's got to be +160F ±10F. If you've turned the unit off, be sure to allow three minutes for warm up prior to reading this temperature.

Reconnect the portable as it was before, [+] lead to the [+] terminal.

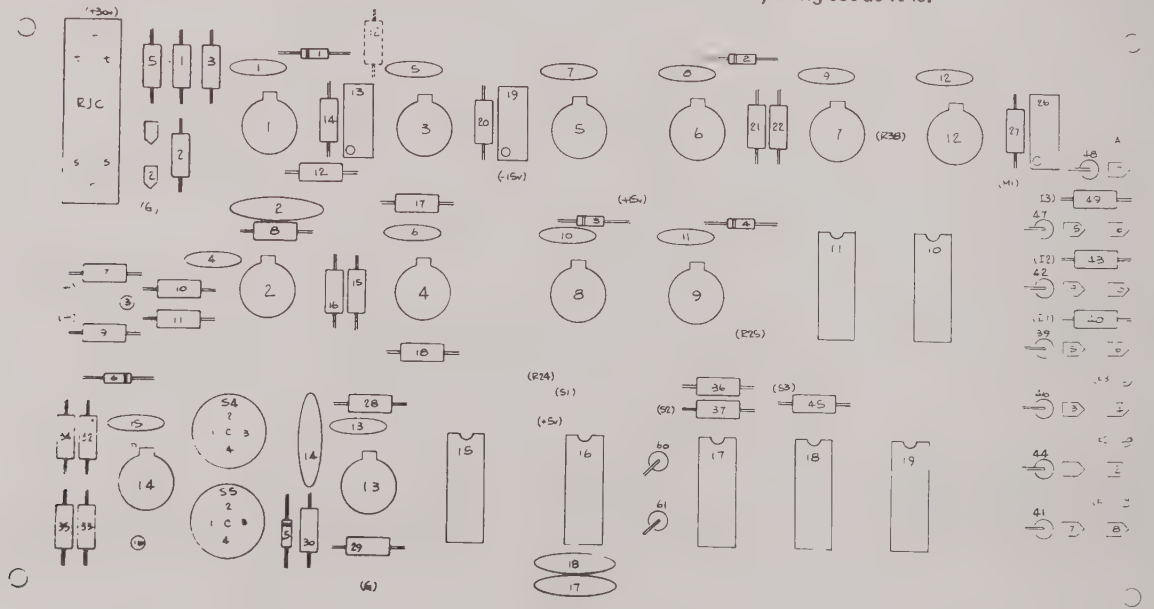
RJC stability

Connect the [+] DVM lead to IC5-6 on the main circuit board. Connect its [–] lead to the can of capacitor C22 on the power supply board.

Now set the portable as necessary to zero the DVM. The DVM should be set on the 200mV range.

With hands off, watch the DVM indication for about sixty seconds. The indication should stay within the range of 0mV±2.5mV.

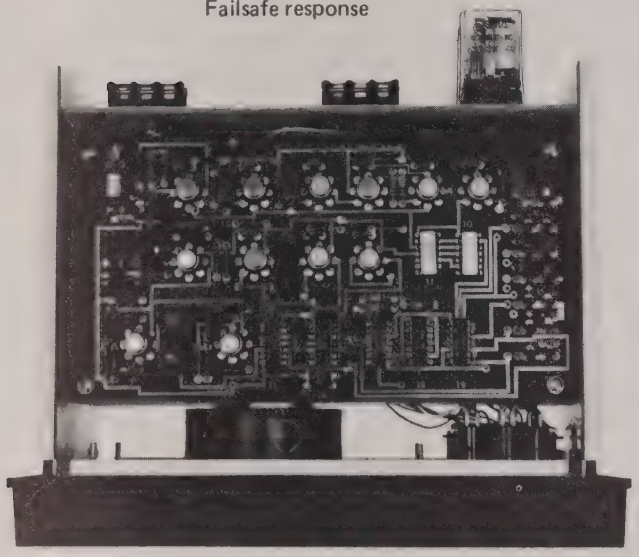
Leave everything set as it is.



Amplifier and Scaling Circuits

This part of the circuit does two things. First it amplifies, or boosts, the weak thermocouple signals up to a usable level. Then it shifts and trims this signal to convert it to a zero to +5vdc analog signal. At its output, the low end of the range is represented by Ovdc and the high end by +5.0 vdc. This signal must be accurately calibrated and free of noise, and so we'll check:

Measuring calibration
Output noise
Failsafe response



measuring calibration

Having just done the RJC checks, you're all set up and ready to go. But zero and span your DVM (if applicable) and the portable, before you charge ahead.

Set the portable to the lowest temperature on the scale (– 125F = – 3.006mV) (mV). The DVM should now read 0.00v. If not, adjust R13 to get this reading.

While you're at this point, check the meter on the front of the unit. If you notice any small error, correct it by turning the mechanical zero adjustment on the front of its case.

Now set the portable to the highest temperature on the scale (+375F = +8.787mV) (mV). The DVM must now read exactly +5.00vdc. If it doesn't, adjust R19 'til it does.

Have another look at the meter. Is it right on the mark? If not, so set it by turning R26.

output noise

Now hook the oscilloscope across the DVM leads. Set the scope at about 20mVac/cm and about 1cm/sec – not critical.

You'll see some 'grass', but there shouldn't be any obvious oscillation or transient spikes. The grass might pulse up and down ±1mV at a rate of about one pulse per second. That's the RJC circuit working; don't worry about it.

The amplitude of the grass, pulses included, has got to be less than 10mV peak-to-peak.

failsafe response

Temporarily disconnect one of the leads at the portable. The DVM indication must now jump to over +10vdc. It's typically +13.5vdc in this condition.

Reconnect the portable and set it to provide a midscale indication.

Failsafe Detector Circuit

The calibrated temperature signal should always be inside the range of 0v to +5 volts. Anything outside these limits is an overrange indication. When this situation occurs, the failsafe detector circuit disables the red and green alarm channels.

What usually causes an overrange indication is a broken or disconnected sensor. When something like this happens, we want to know about it, plus we want to open the red and green contacts in order to disable any heating and cooling equipment until we can restore the instrument's protective function. To assure that this circuit is able to do this, we'll check:

Failsafe detector outputs
Q4 switching

failsafe detector outputs

The portable should be set as left above (midscale). Connect the DVM [+] lead to IC7-6 and its [–] lead to ground, C22's can.

The DVM indication should be about +13.5v. Anything over +12v is acceptable.

Temporarily disconnect one side of the thermocouple wire at the portable. The DVM indication should switch to –0.4 volts; accept anything between 0v and –1 volt.

For a better check, run overrange with the portable, to (– 126F = – 3.023mV) (mV) and to (+385F = 9.080mV) (mV). This checks both overrange and underrange operation. At both settings you should get the –0.4v indication.

Set the portable to provide a midscale indication.

Q4 switching

Connect the [+] lead of the DVM to the top (banded end) of diode CR2. You'll find it near the red relay.

The DVM indication should now be +12v ±2 volts.

Now disconnect one of the 'thermocouple' wires at the portable.

The DVM indication should now be less than ±0.1 volt.

Have a look at the three relays. All three should be off.

At the front of the unit, the yellow light and beeper should be working, with the red and green lights off. This peculiar indication tells you that you're in a failsafed mode. You'll also notice that the indicator pointer is pinned against its off-scale stop, usually on the high end (a downscale limit indication is also acceptable, if less common).

Now reconnect the wire-at the portable, and push all the reset buttons. The DVM indication will return to +12v ±2 volts, all lights are off, no noise, relays all closed. You're back in normal operation.

Automatic Start-up Circuit

The Productsaver has a special circuit which puts it in automatic reset the instant that line power is applied and holds it that way for about 10 seconds. If the temperature comes within limits prior to this time limit, the alarms will latch if you're set for manual reset with auto restart (S4 & S5 in position 2). To check this out:

First, note the positions of the red and green switches S4 and S5, and write them down so you won't forget.

Connect the DVM [+] lead to IC14-6 and its [−] lead to ground, at the can of C22. Set S4 and S5 to position 2. Set the portable for a midscale indication.

The DVM indication should be about −0.4v ±0.4 volts.

Now turn the variac switch off.

When you turn the variac back on, the DVM will read about +4.5v ±1.0v for about 7 to 13 seconds. Then it will switch back to −0.4v ±0.4 volts, with all alarms off.

Turn it on and watch this happen.

Now set S4 and S5 to position 3. Flip the variac switch off, then back on. All three alarm lights should come on, and stay on even after the DVM falls back to −0.4 volts.

At the factory, we leave S4 and S5, the red and green switches, in position 2. In the field, you should return them to the position in which you found them.

Limit Comparator Circuits

These circuits set the limits and compare the temperature signal against the limit settings. They provide an alarm signal whenever the temperature signal goes outside the limit settings.

We're going to check:

Limit adjustments
Limit switching accuracy
Limit signal output levels

limit adjustments

Connect the DVM [+] lead to IC9-2 and its [−] lead to the case of C22, ground.

Turn the green limit adjustment counterclockwise watching the DVM indication fall to 0v. When it stops falling, its indication should be 0v and not more than +5.0mV.

Now go all the way clockwise and watch the DVM indication climb to, and stop at, +5.175v ±0.1 volt.

Connect the DVM [+] lead to IC8-3 and do this same number on the red limit adjustment:

counterclockwise end = +0.005v max.
clockwise end = +5.175v ±0.1v

limit switching accuracy

With the [+] DVM lead at IC8-3, hook its [−] lead to IC8-2.

Now, while pressing the red light, turn the red limit adjustment as necessary to zero the DVM. Near this zero point, find the alarm trip point by turning the adjustment back and forth. At the trip point, the DVM indication can't be more than ±7.0mV.

Set the red alarm back to about (+270F) ( ).

Now hook the [+] DVM lead to IC9-2 and its [−] lead to IC9-3. Holding the green light down, find the trip point for the low limit. Here again, the DVM indication shouldn't be more than ±7.0mV at the trip point. This corresponds to a switching accuracy of about ±0.15%.

Set the green alarm back to about (+30F) ( ).

limit signal output levels

Connect the [+] lead of the DVM to IC8-6 and its [−] lead to the case of C22, ground.

With the portable set for a midscale indication, the DVM indication will be +4.5v ±1.0 volt.

Set the portable to drive the indicator past the high limit setting. Result: the DVM indication falls to −0.4 ±0.4 volts.

Now hook the DVM [+] lead to IC9-6. The DVM indication is, again, +4.5v ±1.0 volt.

Set the portable to something less than the low limit setting, and watch the DVM reading switch to −0.4v ±0.4 volts.

Return the portable to a setting that produces a midscale indication.

Meter Switching Circuit

As you know by now, the meter is used to display three values; the measured temperature, the high limit temperature, the low limit temperature.

Unless you push the red or green light, you'll get the measured temperature reading.

If you've done items 1 through 6 of this procedure, you've had ample opportunity to notice any quirks in this part of the circuit, so you don't have to bother with this if you don't want to. (No choice at the factory.)

Otherwise:

Push the green light and turn the green limit adjustment back and forth a few turns, observing that the indicator pointer is following you.

Similarly, push the red light and turn the red limit adjustment; same meter response.

Now push both buttons at the same time. The indicator pointer will fall to its downscale stop and rest there.

Release both buttons. The indicator pointer should now rise to the correct measured temperature indication. To check it, rock the portable setting back and forth a bit and verify that the pointer follows this action.

Now vary the portable setting as necessary to move the indicator pointer over its full range of travel. Don't go too fast, and watch the pointer as it travels for any sign of friction or 'stiction.' While you're doing this stop at the ¼, ½ and ¾ scale points and tap the side of the meter lightly with your finger. There should be no 'tap' in the meter movement; in other words, you shouldn't have to tap the meter in order to get the pointer to its final resting position.

Limit Circuits and Outputs

These circuits are mostly logic elements. They watch the condition of the limit detector outputs, the reset buttons, the auto-restart circuit and so on; then operate the alarm lights, beeper and output contacts in a manner which is appropriate for the particular combination of 'logical inputs' in effect at any given time.

Such circuit elements have only two logical states; yes—no, high—low, on—off, 1—0, true—false, +5v—0v . . . whatever you wish to call them. This makes such circuitry technically quite simple, yet to trace through it logically gets surprisingly complex. It's almost exactly like a situation you had to face at about age 5; 'This is the dog, that chased the cat, that ate the rat, that nibbled the cheese, that was made from the cream, that came from the cow, that lived on the farm, that . . . ' and so on.

We're not going to play that game here. If any part of this 'electronic brain' isn't working right the outputs will be incorrect in one mode or another. Therefore, we'll just do a 'go—no go' check and watch for output faults. If you run into 'no go' situations in the following check, refer to the 'Circuit Description' section.

SPECIAL NOTE

When doing these checks, remember that output variations are possible as a user option. Most of these variations involve optional connections in the logic circuitry. These alternate connections change the logic as described in the 'Output Variations' section of this booklet.

Set the portable to provide a midscale indication. Then adjust the green limit to about the 1/3-scale position, and the high limit to about the 2/3-scale position.

Note the position of the red and green switches, S4 and S5, then set them to position 1.

Set the portable to produce just less than a full scale indication. Check these:

*Red light on
*Yellow light flashing
*Beeper beeping
*Yellow C and N.C. contacts made, 0.1 Ohms max.
*Yellow C and N.O. contacts open, 2.0 Megohms min.
*Red C and N.C. contacts made, 0.1 Ohms max.
*Red C and N.O. contacts open, 2.0 Megohms min.

Reset the portable to provide a midscale indication. Go conditions are:

*All lights off
*Beeper off
*All C and N.C. contacts open, 2.0 Megohms min.
*All C and N.O. contacts made, 0.1 Ohms max.

Set the portable to provide an indication which is just above the lowest point on the scale. Find:

*Green light on
*Yellow light flashing
*Beeper beeping
*Green C and N.C. contacts made, 0.1 Ohms max.
*Green C and N.O. contacts open, 2.0 Megohms min.

Push the yellow light. That should:

*Silence the beeper
*Turn the yellow light on steady (no flashing)

Reset the portable to provide a midscale indication. Here's how:

*All lights off
*Beeper silent

Using the portable, run the indicator pointer up to almost full scale, then return to a midscale indication. Result:

*Red light on
*Yellow light flashing
*Beeper beeping

Now push the red light. Output status:

*All lights off
*Beeper mute

Similarly, run the indicator pointer down to just above the low end of the scale, then return it to a midscale reading. Verify this:

*Green light on
*Yellow light flashing
*Beeper beeping

Push the green light, and see:

*All lights off
*Beeper quiet

Now set the red and green switches, S4 and S5, to position 3. Using the portable, run the indicator pointer way down and off the bottom end of the scale. *Observe:*

*Yellow light flashing
*Beeper beeping
*Red and greed lights off

Then return the pointer to just on the temperature scale. The result will be the same as it was, *except:*

*Green light on

Now run the indicator pointer way off the top end of the scale. *The proper response to this is:*

*Yellow light flashes
*Beeper beeps
*Red and green lights off

Now recover a reading of just under the highest point on the scale. *You should now have:*

*Yellow light flashing
*Beeper beeping
*Green light on
*Red light on

Now return to a midscale indication on the meter. This shouldn't change the above listed observations.

Push all three lights to turn them off and quiet things down. Now switch the variac off for a second, then back on. *The correct response is:*

*Yellow light on (not flashing)
*Red and green lights on
*Beeper off

Reset the red and green switches to their original positions as noted earlier. At the factory we set them to position 2.

Noise Immunity

At best, this check is none too good since it's impossible to duplicate all of the *'noise'* possibilities that the instrument might encounter. It's also almost impossible to specify a *'standard noise'* for test purposes.

At the factory, experience has taught us that the most reliable test, as related to practical applications, is not a *'technically sophisticated'* procedure which is carried out under closely controlled laboratory conditions. Much to the contrary, we have evolved to a *rather 'gross' procedure* through our efforts to assure that this product, in particular, can withstand all but the *'most downright unreasonable' assaults of electrical interference.*

Some time ago we found that the worst *'noise generator'* on our premises seemed to be an old *Remington–Rand* mechanical calculator machine. We reasoned that *'if it can withstand that, it can withstand just about anything,'* and since we started using this procedure, we've had *no 'noise problems'* that I can recall.

The procedure is simple. We plug the calculator into the same line as the variac. The limits are set five scale divisions [±5%] to either side of the indicated temperature near the middle of the scale. Then operation of the calculator must not trip the alarms. It does cause the indicator pointer to 'jump' about two scale divisions now and then, which we deem acceptable so long as no alarms occur.

From an application's point of view, it is particularly important that this particular product be able to withstand some rather high levels of electrical interference. False alarms and false shut downs can be a disgusting and disruptive nuisance.

You can closely duplicate our test method by using a common timer motor (a small low-torque syncronous motor such as *General Time*'s type *RG21*) connected through a pushbutton switch to the input power terminals on the back of the instrument.

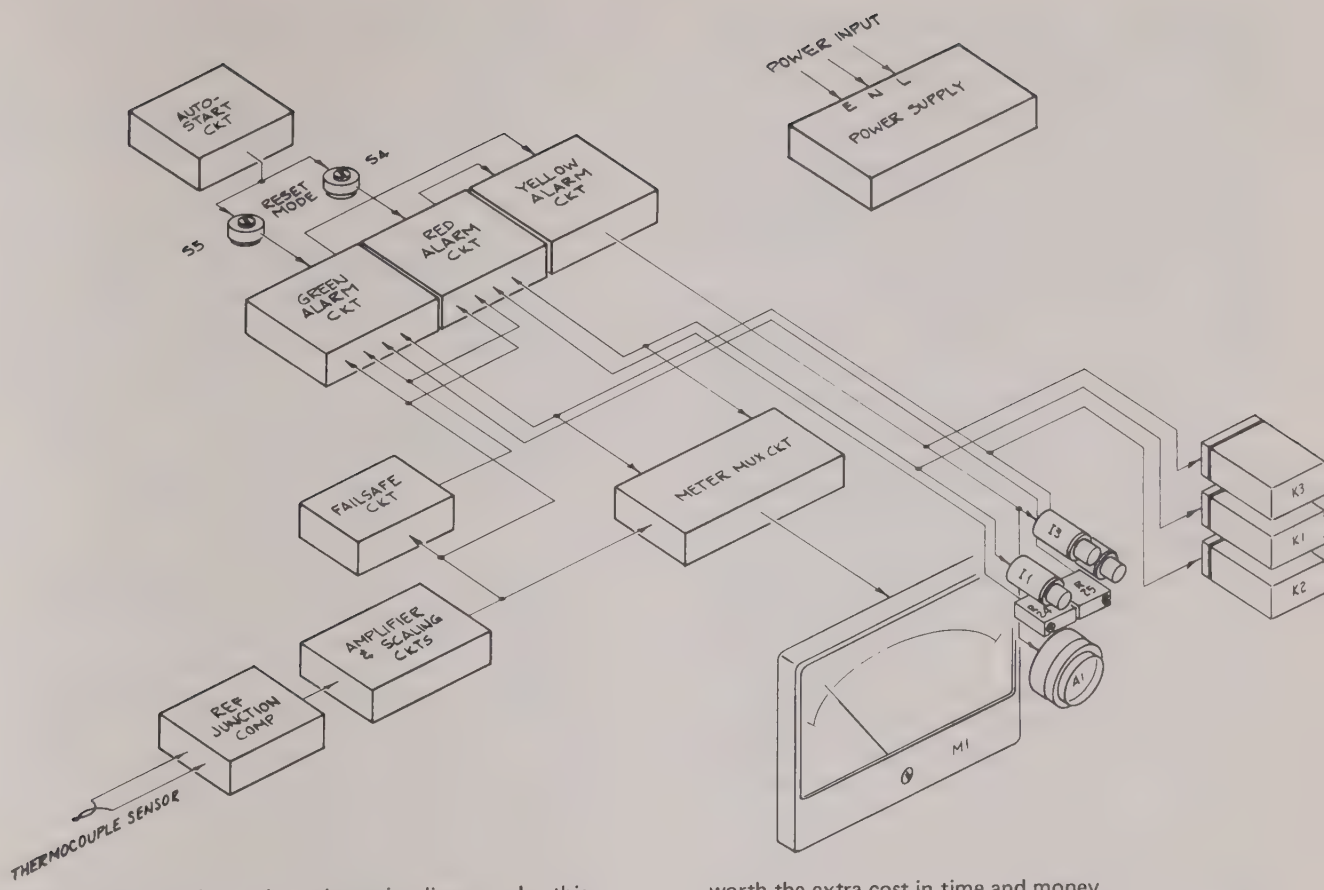
If you detect noise problems, first recheck the power supply regulator circuits; then check capacitors C2, C3, C10, C11, C17, and C18.

If you have noise problems when the instrument is in use, one thing is certain. It's always easier to stop the noise at its source, than it is to stop its effects in any affected instrumentation. This is generally because such interference is high frequency (radio frequency) energy and propagates quite freely. No matter how many holes you plug around the affected area, it'll still find a way to get through. On the other hand, a syncronous motor (one of the worst offenders when switched on and off) can be quieted down by simply connecting a 0.01mfd 1500v disc capacitor across its leads at a cost of less than a dollar. A similar treatment will 'fix' most other types of small motors, including those in calculators and electric appliances, whose *'noisy'* condition might also indicate that new brush-blocks are required. Arcing relay contacts can usually be quieted by a simple RC arc suppression network, which will also help extend the life of the contacts.

CIRCUIT DESCRIPTION

This section tells you how the instrument's circuitry works. As you'll see, the circuit can be broken down into several sub-circuits, each of which has its own little task to perform. Look at the blocked schematic diagram. We'll see what each one of these parts is supposed to do and how it does it. In the process we'll cover the function of each component part shown on the schematic diagram.

Some handbooks provide a 'simplified explanation' in connection with a block diagram and then a 'detailed circuit



analysis' referenced to the schematic diagram. In this manual these two treatments are integrated to form this general explanation of what it's for and how it relates to the rest of the circuitry; then this is followed by a detailed explanation of how it works. So, if you're looking for a 'simplified explanation,' read only the first few paragraphs of each section without going on to the detail. If you want to know all about it, read the entire section.

DC Power Supply System

The dc power supply system provides the *'juice'* for all the circuits in the instrument. You can compare it to your heart. If your heart isn't in very good shape, your capabilities are going to be limited. A person with a weak heart won't be able to keep up with a person whose ticker is strong and healthy. It's the same with an instrument such as this. An A-1 power supply, kept in good shape, is well worth the extra cost in time and money.

The dc power supply system provides five voltages for the instrument's other circuitry:

+30vdc unregulated
+12vdc unregulated
+15vdc regulated
−15vdc regulated
+5vdc regulated

A −30vdc unregulated potential is also developed as source power for the −15vdc supply.

Let's look at the +12vdc supply first, since it's the simplest. The 12v potential is used to operate the three alarm lights, the three relays and the beeper. That's all. These particular items will operate quite satisfactorily over a fairly wide voltage range. The high limit is related to the light bulbs. They're rated for 14v; higher voltages will make them burn out much too fast. Lower voltages will greatly lengthen their life. But then the relays are rated for a minimum pick-up voltage of about 8v, so we can't go much lower than that. So we should try to stay within a range of 12v $\pm$2v at all times.

Transformer T2 steps down the line voltage from 115vac to about 24vac. The 24vac is developed in its secondary

winding. Since the secondary is center-tapped, we'll have 12vac on either side of it with respect to ground.

One end of the secondary is connected to diode CR14, and the other end is connected to CR15.

'Ac' stands for *alternating current.* What *'alternates'* is its direction. The line current in the primary winding reverses direction, *alternates,* sixty times per second.

In connection with this, the polarity of the voltage on the primary, and that developed in the secondary, also alternates, or reverses, sixty times per second.

The diodes are sensitive to this polarity reversal. When the polarity on their anode is [+] they'll conduct current with little opposition. When it's [−] they'll block current.

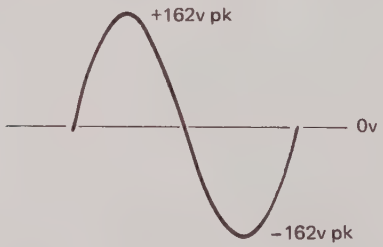
When the top of the secondary is [+], its bottom will be [−]. CR14 conducts, CR15 blocks. Current flows from the center tap into ground, through the loads (relays, lights, etc.), through CR14 from cathode to anode and back to the top of the secondary. No current flows in the bottom half of the secondary.

When the polarity reverses, CR14 blocks and CR15 conducts. The current path will be the same except that it flows through CR15 instead of CR14, and the top half of the secondary will be dead.

Notice that the current always flows through the load in the same direction. It's a direct current, also called *dc.*

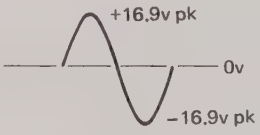
This transformer-diode connection is called a *full-wave rectifier circuit.* It converts *ac* to *dc.* It's quite a common circuit.

The ac input does not change abruptly from +115v to −115v. It is not a square wave. Instead, it changes smoothly as shown here.



This is called a *sine wave.* Even though it peaks out at ± 162v, your voltmeter measures 'the average' rms value, 115 volts.

On the secondary side of the transformer, we have a similar situation between the center tap and either diode.

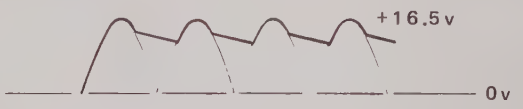


At the junction of the diodes, if C29 is disconnected, here's what we'll have.

Notice that we've lost 0.4 volts from the peak value. This is lost at the diodes, it's their forward voltage drop.

Now notice that our supply voltage is, on the average, about +12v, but it drops to zero 120 times per second. This is no good. It'll make the relays buzz and the beeper warble.

To get away from this, we'll reconnect C29, which filters the output, so that it'll look like this.



This is how it works. When the voltage wave goes high, C29 charges as fast as it can, and will charge up to about 13v by the time that the wave starts to fall.

Now while the voltage wave falls to zero, C29 takes over and supplies current for the load by discharging through ground, the load and back into its [+] side. C29 is large enough so that is doesn't discharge 100% prior to the next positive wave. In this manner, load current is provided constantly.

This instrument is rated for 115vac line power, but must tolerate variations between 90vac and 130vac, or 78% to 113% of its rated input. Since the +12v supply isn't regulated, it'll vary with the line voltage, from about +9.35v to +13.6. In the beginning, we shot for 12± 2v, with an 8v minimum and a 14v maximum. So we're in good shape here.

The +12v supply will also vary somewhat with its load, but not much. This is because its load is normally balanced quite well. The beeper load is too small to count. The lights and relays both draw about the same current, about 65mA to 80mA. Since there will always be some combination of three (lights and relays)on, the load on this supply is fairly constant at about 210mA.

One last note. Look at the 'E' connections at the transformers. These transformers have a shield between their primary and secondary windings. Its purpose is to keep high frequency noise on the line from getting into the instrument. It only works when the 'E' terminal is connected to a near-by water pipe or ground rod (earth), using wire no smaller than AWG 16.

Now let's go on to the +30v and ± 15v supplies. Since we've spent so much time in the +12v unregulated section, we won't go into detail about the +30v and −30v unregulated supplies. We'll only talk about what's different.

First, the transformer is different. Its secondary is rated for 42vrms, so on either side of T1's center tap, we'll have about 29.5v peak.

Here we use a single transformer to serve two full wave regulator circuits. Notice that CR11 and CR13 are 'backwards,' and so is C23. These three parts make up the –30vdc unregulated supply, CR10, CR12 and C22 make up the +30vdc unregulated supply.

The +30v supply is used as input power for the +15v regulator, and also for heater power by the RJC circuit. The –30v supply is used only as input power for the –15v regulator. When the RJC heater switches on, the +30v level will drop for a moment to about +24v, and the –30v level will also drop somewhat, to about –29v.

For these supplies, anything between 20v and 35v is acceptable. For the RJC circuit, the higher voltage speeds up warm up somewhat, but the lower voltage results in somewhat closer control of the rj temperature. So either condition is 'better' for that circuit.

The regulator circuits require a minimum of +19v and –19v at their inputs. So the unregulated supplies must not fall below this limit at any time.

IC21, et al, is the +15v regulator. IC22 and it's periferal parts form the –15v regulator. These two circuits work together.

Inside IC22 there is a constant current source between pins 1 and 2. Resistor R58 sets the value of this current at about 1.0mA. This current flows from C23 through resistors R58, R57, R56, R55 and R54 to the +15v terminal.

Inside IC21 there is a precision voltage source that generates a reference voltage of +1.7vdc.

IC21 wants to match up the voltage on pin 6 with its reference voltage. In other words, it wants to see +1.7v at pin 6.

So let's set R55 at 600 Ohms. Now *R54 + R55 = 13.3K.* Since we have a constant 1.0mA through these two resistors, there is a voltage drop of 13.3v across them. What voltage do we need at the top of R54 so that pin 6 will be +1.7 volts? We need 15 volts.

$$15v - 13.3v = 1.7v$$

If the output is 14.9v, pin 6 will be

$$14.9v - 13.3v = 1.6v$$

Pin 2 of IC21 will now supply slightly more current into the base of transistor Q19. Q19 then allows a little bit more current to pass through the load, which increases the voltage drop across the load to +15v. IC21 finds this correct operating point, then holds it constantly by varying the 'resistance' of Q19 as required.

The operation of IC22 is a little different. The workings of IC22 are such that the voltage at its pin 8 must always be twice the voltage at pin 1, which is its reference.

So what's the voltage at pin 1? This is easy.

Starting at the +15v supply, we drop 12.7 volts across R54, leaving +2.3 volts. Since R55 = 600 ohms, we drop 0.6v here, leaving +1.7 volts at IC21-6. Next we drop 8.45v across R56, leaving –6.75v at the wiper of R57. Now set R57 for 750 Ohms, and drop another 6.75v, leaving –7.5 at pin 1 of IC22.

IC22 then operates Q20 such that enough current is passed through the load to produce a voltage drop of $2 \times -7.5 = -15v$, as sensed at IC22-8. This is done by controlling Q20's base current from pin 7.

These two regulators hold the ± 15v levels constant regardless of line and load variations. That's their main job. They also get rid of the ripple that rides the unregulated supplies. So we wind up with nice clean pure dc voltages as our main supply for the instrument's circuitry.

These two regulators also provide current limiting action. This protects the power supply itself and, to some extent, the rest of the circuitry. For instance, you can short the regulated supplies directly to ground and it won't hurt a thing. They'll automatically protect themselves.

The current limit for both regulators is 125mA, and this is set by the values of R50 and R59.

On the positive regulator, IC21, all the +15v load current, plus the +5v load current, flows through R50, a three Ohm resistor.

When the total load current approaches 125mA, there will be a voltage drop of about 375mV across R50. IC21 monitors this between pins 1 and 8, and begins to reduce the output voltage so as to stop the load current from increasing any further. If it has to turn Q19 almost off in order to maintain a constant 125mA maximum, that's what it will do.

IC22 works the same way, except that the current limit sense voltage is about 640mV (125mA x 5.1 Ohms). The current limiting action is a *constant current* type of action. When the load current reaches 125mA, it will be held at that limit until the cause of this excessive load is removed.

You can check the load current on the regulated supplies by measuring the voltage drop across R50 and R59, then dividing by the resistor values. You'll find that the loads usually run about:

+15v and +5v: 195mV ÷ 3 Ohms = 65mA
–15v: 230mV ÷ 5.1 Ohms = 45mA

Do yourself a favor, and remember about this current limiting action. If you have troubles and discover that the supply voltages are way off, check the load currents before you readjust or start to *'fix'* the regulators. If something in

the load circuitry goes bad and draws excessive current, the low voltage situation is a correct reaction on the part of the regulator circuit involved. There's nothing wrong with it.

We're going to talk about some features which are common to all three regulators, then we'll also consider some troubleshooting facts. But first we'll cover the operation of the +5v regulator.

IC20 and its friends regulate the +5vdc supply voltage. This IC is the same as IC21, except that we're using a slightly different feedback scheme.

You'll recall that the regulator circuit is going to do whatever's necessary to get +1.7v at pin 6. In this case we're getting this feedback information off a simple voltage divider, R51, R52 and R53. We're going to set R10 so that we'll get this +1.7v level when the output is exactly +5 volts. Here's how:

$$1.7v \div 5.0v = 0.34$$

or, 1.7v is 34% of 5.0v

This tells us that the resistance between pin 6 and ground has to be equal to 34% of the total *R51 + R52 + R53.*

If R53 equals .34 times the total resistance, or

$$R53 = .34RT$$

then this formula can be converted to

$$\frac{R53}{.34} = RT$$

Since *R53 = 3.09K,* the total *R51 + R52 + R53* is

$$RT = 3.09K \div .34 = 9.09K$$

To get the value of R52 all we have to do is subtract R51 and R53 from this.

$$\begin{array}{r} 9.090K \\ -\,4.990K \\ -\,3.090K \\ \hline 1.010K \end{array}$$

Check this out with Ohm's Law.

As we explained in connection with IC21, if the voltage on pin 6 of IC20 drops below 1.7v, that's the signal that the +5v level has dropped. So IC20 turns on Q13 a little more to get a bit more load current, which returns the voltage drop across the load to exactly +5 volts. If pin 6 goes a little higher than 1.7v, the reverse action occurs, with Q13 throttling the load current as necessary to bring the load voltage drop back down to +5 volts.

This jockeying back and forth happens so fast that you can't see it, except on a good oscilloscope; a few millionths of a second is all that's required to make these little corrections.

The +5v supply is ultra good because it's double regulated. As you can see, its voltage source is the regulated +15v supply. The reason for this is mainly that this supply circuit was developed for another type of instrument where we needed a real good +5v level in addition to +15 volts. For this unit, this kind of perfection isn't really required. But it doesn't cost you any more, so we decided to use this circuit anyway. You got a bonus.

Current limiting for the +5v supply is taken care of by R50 and IC21. If you get an over-current condition on the +5v buss, IC21 will shut down the +15v supply, which provides source power for the +5v system. So you're fully protected here, as well. So much for the +5v supply.

Now look at capacitors C24 and C25. These are compensation capacitors for the LM305A IC's. Without them, these regulators will oscillate at some very high frequency . . . millions of cycles per second. So the dc outputs will become ac, which won't work. The LM304 has this capacitor built in.

Capacitors C26, C27 and C28 compensate for a reaction between the outputs of the IC's (pins 2 and 7) and the base of their friendly pass transistor. These are *solid tantalum* capacitors. If you ever have to replace them, be darn sure that you use only solid tantalum, since most other types won't work.

If one of these capacitors goes bad, what you'll see is a high frequency oscillation (megahertz) riding the dc output of that regulator. You'll also see this if someone replaces one of them with something other than solid tantalum. This high frequency stuff propagates like wild fire, and you'll find it all over the circuitry.

Until you discover it, you'll have the feeling that things just don't seem quite right, although everything seems to be working. You'll think that what's wrong is that this particular instrument is just a lemon.

One of the problems is that this stuff doesn't usually show up on a dc DVM, your chief troubleshooting tool. You have to use a scope to discover this trouble. The next problem is that you'll see it on all the supplies, not just on one of them. So you won't know which capacitor is bad.

To find the bad one, first check the picture in the parts list against the power supply board, to see if someone has replaced a tantalum with an electrolytic capacitor. If so, that's the problem. Otherwise, take your soldering iron and heat up each capacitor at its connection to the circuit board, one at a time, while watching the scope. Quite often, a bad one will work better when it's hot, and you'll see the oscillation on the scope disappear, or at least diminish, when you hit the dud. If this doesn't work out, replace these capacitors one at a time until you get the bad one out of the circuit.

Whenever you check the regulated voltages, you'll find them within about $\pm$ 0.3% of their specified level. If not,

check the load current before you do anything else. If the load current is more than 100mA, something's wrong out in the load circuitry. Something out there is drawing too much current. Look for a hot spot, especially a hot IC.

The +15v current limit interacts with the −15v supply. This is because when the +15v level drops, the voltage at pin 1 of IC22 increases, and IC22 will try to jack up its output to suit, not knowing that IC21 is current limiting. For instance, if +15v drops to zero, IC22-1 will go to −22v, so IC22-8 will attempt to reach −44 volts. This isn't especially dangerous, since IC22 is also equipped with current limiting.

But if you're not careful, you'll jump to the conclusion that Q20 must be shorted, because you're measuring the −30v unregulated level where you should see −15 volts. The reverse situation occurs when the −15v supply current limits; it'll drive the +15v supply way off the beam.

Whenever you've got one high and one low, work on the low problem first and, again, look for a load problem first. If you correct a fault in the load, the regulators will usually correct themselves.

The pass transistors sometimes do go bad. When they do, they usually short. When this happens, the regulator IC tries to take over their job, and usually burns itself up in the process because it can't handle the power dissipation. As a rule-of-thumb, if you ever have to order a pass transistor, you'd better also order its associated IC. Then replace the transistor first and see if it works before replacing the IC.

The Sensor Loop

To understand this circuit, you have to know something about thermocouples.

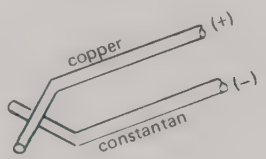
Thermocouples are made by connecting unlike types of wire together. We're going to talk about copper and constantan (type T) here, but there are several other standard combinations which are quite common. Among them are:

iron vs. constantan	(J)
chromel vs. alumel	(K)
chromel vs. constantan	(S)

Different types have different response curves, different temperature ranges, and are physically more suited to special environments. For instance, iron isn't very good in moist environments because it rusts too fast. Other than this, all thermocouples work the same way.

Here's some facts about using thermocouples that you ought to know.

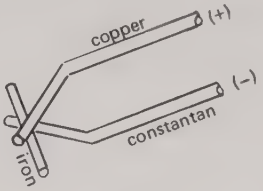
1.



All you have to do to make one is bring the two wires into contact. They don't have to be soldered, welded, spliced, crimped, or anything else. The instant they contact each other, they start working; the junction is formed. Only if you want to make sure that it keeps working must you weld or solder the connection. That's obvious.

The point is, electrically, no special treatment is required. The junction will generate a small voltage (emf) that is proportional to the heat in the wire.

2. Let's make a thermocouple with three different types of metal. Have a look at this, and see if you can predict how it'll work:



The answer is that the third metal probably isn't going to mean anything . . . you've still got a copper constantan thermocouple.

You've got two junctions alright enough. The iron-constantan junction has a response all its own, and so does the copper-iron junction. But they are not the same, and when they cancel against each other the net response will be the same as if there wasn't any iron there, so long as they're both at the same temperature.

In fact, you could put a hundred different types of metal between the copper and constantan and it won't make any difference, as long as the whole mess is at the same temperature.

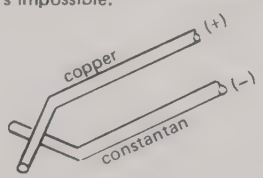
There is a 'law' that says intermediate metals don't count. That's why you can solder thermocouples and they'll still work perfectly, even though the solder has tin, lead, and who knows what, in it.

3. Don't assume that you have to have special types of metal to make a thermocouple. It's safer to assume that you have to have special types of metal to not make a thermocouple, or to make a not thermocouple.

Have a look at the circuit board assemblies. Would you believe that the leads of the IC's and the circuit board pads make good thermocouples? It's true. The response of these junctions is about the same as a copper-constantan thermocouple. The circuit board conductors are copper, and it just so happens that the IC leads are a nickel alloy similar to constantan.

But almost any combination of dissimilar metals is a thermocouple to some extent. Each such junction will generate a small emf equivalent to its heat. In order for this to be useful, we need to know **exactly** what the temperature vs. emf response of the junction is. This we get from the National Bureau of Standards only for standard combinations, like those given above, so that's why we use one of those types as the temperature sensor.

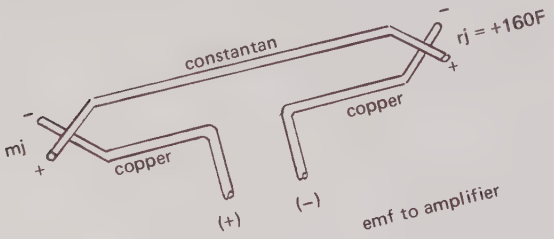
4. It would be nice if we could make just one junction and use it as a sensor. But that's impossible.



We can connect the copper wire to our copper circuit board, and that's ok . . . no junction at that connection. But what are we going to connect the constantan wire to?

No matter how many metals you put between this wire and the circuit board, you're still going to wind up with a second copper-constantan junction. It'll be temperature sensitive. Its emf will buck that from the measuring junction and cause an error in the temperature measurement. That's a fact which can't be changed.

So here's what we're going to do. We're going to wire up the sensor like this:



Here, we've intentionally made a second junction with copper-constantan thermocouple wire. We're calling it the *reference junction*. This we put into an oven which we'll hold *very precisely* at some temperature around 160F.

So we've now got an error, but we'll know exactly what it is at all times. After we amplify the signal, we'll put it through a circuit that will automatically subtract this error for us, so we'll have only the *mj* signal left, which is what we want *(mj = measuring junction).*

We're going to be particular about how we connect the copper leads to the copper circuit board, and into the amplifier. For convenience, we'll have screw terminals, so we've got to make sure of two things. First the metal sequence on the [+] side has to be exactly the same as the metal sequence on the [–] side. Second all complimentary junctions have to be isothermal. What does that mean?

That means, for instance, that the two screw-copper junctions must always change temperature at the same rate. In this way they'll cancel each other's *emf* out, and there'll be no error caused by these junctions. We've designed this into the instrument. If you look at the component layout around the input to the amplifier IC, you'll notice that things are fairly symmetrical around pins 2 and 3.

If you have to do any work on the circuitry between the measuring junction (sensor) and pins 2 and 3 of IC2, make sure that this symmetry is preserved. For instance, don't leave a big blob of solder on pin 2 and a small blob on pin 3. Two big blobs or two small blobs (preferred) will cancel. But where you can see obvious physical differences, you're probably looking at a source of measuring errors.

Thermocouples are about the cheapest sensors that you can get your hands on. But that doesn't mean a thing. Their response time beats most other types of sensors, and they're darned accurate when used with a little care and common sense. The chances are that any error coming from your sensor is going to be less than ±0.10F. That's less than ±200 parts per million, and that's pretty good.

Reference Junction Control Circuit

This circuit is a little temperature control system in itself. Its job is to heat the reference junction (rj) up to about 160F, and hold it very precisely at that temperature.

The ellipse represents the walls of our little oven. Inside we have a heater (R6), the reference junction (rj) and a thermistor (R4) which is used as the temperature sensor for the oven.

A thermistor is like a resistor, but its resistance varies with its temperature. As its temperature goes up, its resistance goes down. For instance, R4 = 100K @ 77F, but R4 = 12.7K @ 160F.

Now have a look at R1 and R2. This is simply a voltage divider. It cuts the +15v supply voltage in half so that we have +7.5v at IC1-2.

Then look at R3 and R4. Same thing here, but only when R4 is at 160F, when its resistance will be about 12.7K. At this point, the voltage applied to IC1-3 will also be +7.5v. So both inputs of the IC will be balanced when the oven temperature is about 160F. That's its control point.

Suppose that we start by turning the instrument on. At this point, the oven will be at about room temperature and R4 will be about 100K.

You can figure out, by Ohm's law, that the voltage at IC1-3 is going to be about +11.8v at start up.

What the IC does is compare the input at pin 3 to the input at pin 2. If pin 3 is [+], it switches its output (pin 6) as far [+] as it can. If pin 3 is [–], it switches its output [–] to the limit. The IC is *very sensitive,* and can detect differences as small as 15uV, equivalent to only a fraction of a degree. Its output tries to swing to the value of the ±15v supply voltages and usually *'saturates'* at about +13.5v (on) and –0.4v (off).

So right now the oven is cold and pin 3 is therefore [+]. The output at pin 6 will be +13.5v, or more.

When the output is [+], it pulls a current of a little over 1.0mA through the base of transistor Q1. This *'turns on'* Q2, which acts like a switch. With Q2 on, resistor R6 is connected right between the +30v unregulated power supply and ground, and a current of about 100mA shoots through it. This causes R6 to get hot, since it's power dissipation is about 2400mW. Within about sixty seconds, the oven will be at about 160F.

The thermistor is drilled right into the core of R6, but it's always a hair slow, so the oven temperature will overshoot slightly. This means that the value of R4 will be driven to something slightly less than 12.7K.

When this happens, the voltage at IC1-3 will be just less than +7.5v, or [–] as compared to pin 2, so the IC will try to switch its output to –15v.

It won't make it though, because diode CR1 stops it dead at about –0.4 volts. We do this so that we won't draw any current through the transistors backwards, through their base-collector junctions.

When the output goes just slightly [–] like this, the base-emitter junctions of the transistors are cut off, which turns off Q2 and the current through R6.

R6 now begins to cool off. As it does, the resistance of R4 begins to increase, which increases the voltage at pin 3. When pin 3 becomes [+] with respect to pin 2, Q2 will be turned on again. And so we have a complete on-off-on cycle. This action continues over and over again as long as the instrument is operating. The result is that the oven temperature is held within about ±0.1F of its operating point at all times.

Resistor R5 simply limits the base current of Q1 to about 1.0mA, which is more than enough to turn on Q2 real hard. Capacitor C1 is used to control the frequency response of IC1, to be sure that it doesn't produce any high-frequency oscillation as its output slews through the linear region between [+] and [–] saturation extremes.

The design point of the oven temperature is +160F. Due to tolerances in the parts, mainly in the thermistor, the control point might not be +160F right on the nose. Within limits, this doesn't make any difference because we can adjust for small offsets. What is important is that the temperature, whatever it is, must remain very stable. Any temperature between +150F and +170F is acceptable so long as it doesn't cycle or drift around more than ±0.1 deg. F.

Amplifier and Scaling Circuits

In order for the instrument to do its job, we need a temperature measurement. This is provided, basically, by the thermocouple sensor (mj) in the form of an *emf* that varies with temperature. Let's look at what we have to work with when the thermocouple is copper-constantan and the instrument's range is –125F to +375F.

According to the table for this thermocouple, its output at –125F is –3.006mV, and at +375F it is +8.787mV. So over the temperature range, the thermocouple *emf* will vary over a span of

$$-3.006\text{mV} \text{ to } +8.787\text{mV} = 11.793\text{mV}$$

Since we have a range of 500 degrees, the average sensor response is

$$11.793\text{mV} \div 500 = 23.6\text{uV/Deg.F.}$$

This is a very weak signal. In the average application random electrical noise will probably be at least ten times 23.6uV. Also, we're going to want to compare the measured temperature with a set value of temperature, and produce a logical signal that means 'higher than' and 'lower than.'

To do this comparing, we'll probably use an LM301A integrated *op* amp, which has a sensitivity of about 200uV. Since the sensor response is about 24uV/Deg.F., we can see that our comparator wouldn't be very sensitive. It would take a temperature change of about eight degrees to switch this circuit from one state to the other. Between the 'higher than' and 'lower than' extremes we'd have a zone about eight degrees wide where it would be uncertain.

This isn't what we want. We want clean, crisp switching without any uncertainty. In order to get this, we'll have to boost the response of the measuring circuit. How much?

Let's say that we want the switching sensitivity to be better than ±0.1F. In this case ±0.1F is going to have to be at least ±200uV. The sensor response itself is ±0.1F = ±2.36uV. So you can see that this signal will have to be multiplied by 100 times at least, and the more, the better.

What we're going to do is this; we'll multiply the thermocouple signal by about 424, and convert its *–3.006mV to +8.787mV signal* to a *0v to +5v output signal*.

IC2 and its associated parts does the multiplying. Here's how it works.

IC2 will do whatever it has to do to set the voltage on it's pin 2 equal to that on pin 3. Notice that R7 and R8 form a voltage divider between it's output, pin 6, and ground. A fraction of the output voltage is tapped off at pin 2.

Resistors R10 and R11 serve to protect the inputs of the IC only. They have no other part in the operation of the circuit. Resistor R9 is added simply to balance the input circuits of the amplifier, and help to eliminate small errors. It, too, has no part in the amplification process. For all practical purposes, R9, R10 and R11 can be ignored.

Now suppose that the thermocouple *emf* applied to pin 3 is exactly 1.21 millivolts. In order to get pin 2 balanced at this level, a current of 1.0uA must flow from ground, through R7, R8 and into the output of the amplifier at pin 6.

In order for this to happen, pin 6 must go positive. So we already see that this is a non-inverting amplifier. In other words, when the input signal goes [+], the output signal will also go [+].

How far in the [+] direction does pin 6 have to go to draw 1.0uA through R7 and set pin 2 equal to pin 3?:

pin 3 = +1.21mV
pin 2 = 1.21K x 1.0uA = +1.21mV

The answer is real easy. The total resistance of the voltage divider is

R7 + R8 = 1.21K + 536K = 537.21K

For a current of 1.0uA to be drawn through this much resistance, pin 6 must be set at

E = 1 x R = 1.0uA x 537.21K = +537.21mV

Since the input signal was +1.0mV and the resulting output signal was 537.21mV, the gain of the amplifier is

$$Av = \frac{Eout}{Ein} = \frac{537.21mV}{1.21mV} = 445.0$$

Now let's see how the amplifier handles the thermocouple signal really.

When the temperature of the measuring junction is -125F, its *emf* is -3.006mV. As you know, we're holding the temperature of rj at +160F, and at this point its *emf* is +3.006mV. Note that the mj signal has reversed polarity. So with respect to IC2-3, the total input *emf* is

mj @ -125F: -3.006mV
rj @ +160F: -3.006mV

Total *emf*: -6.012mV

The gain of the amplifier is 445, non-inverting, so for this signal its output at pin 6 will be

-6.012mV x 445 = -2.76 volts

At the high end of the range, the input and output will be:

mj @ +375F: +8.787mV
rj @ +160F: -3.006mV

Total *emf*: +5.781mV

Pin 6 = +5.781mV x 445 = +2.57 volts

So over the temperature range, the output of the amplifier swings

from: -2.76v @ -125F
to: +2.57v @ +375F

Total: 5.33v

In the beginning, we said that we wanted a 0v to +5v temperature signal. This we will get. The gain of the amplifier circuit has been intentionally made a little high, so that we'll have some room for adjustment later on. That's why we got a 5.33v change instead of exactly a 5v change. We'll correct that later.

The amplifier circuit also serves as an electronic filter. Capacitor C3 blocks dc current, but readily passes ac signals such as noise voltages. Its function here is to cross-couple noise signals between the two inputs. When the two inputs are equal, the output isn't forced to change. So if we have the same noise signal at both inputs, it won't be reproduced in amplified form at the output. C3 is a tantalum capacitor, which offers little resistance to high frequency noise signals.

C2 has the effect of reducing the gain of the amplifier for ac signals. Since a capacitor has a low resistance value for ac signals, while blocking dc current, we have in effect, two voltage dividers. One for ac signals through C2 and one for dc signals through R8. For a 60Hz signal, C2 looks like a 26.5K resistor; at 6000Hz it looks like a 268 ohm resistor. The lower this value goes, the lower the gain goes. At 6KHz, for instance, the gain is only about 1.5. So a noise signal at this frequency will get through the amplifier, but with very little amplification.

This is a very important job of the amplifier. It boosts our dc *emf* signal, but not any noise signals associated with it. This is called *increasing the signal to noise ratio.* When we get to the comparator circuits, excess noise would really mess up the operation. So that's why we have to get rid of it.

Now let's cope with our zero and span problem. What we want is:

-125F = 0v
+375F = +5v

What we've got at the amplifier output is

-125F = -2.76v
+375F = +2.57v

Here's how we'll correct it. First, we'll add +2.76v to the temperature signal, then we'll divide it by 1.066. The result will be:

At -125F: IC2-6: -2.76v
+2.76v
0v

and, 0v ÷ 1.066 = 0v

At +375F: IC2-6: +2.57v
+2.76v
5.33v

and, 5.33v ÷ 1.066 = 5.0v

This is all done electronically by IC's 3, 4 and 5.

The +2.76v that we're going to add to the temperature signal comes from IC3. R12, R13 & R14 form an adjustable voltage divider which is connected between our regulated +15v supply and ground. By providing a little bit of adjust-

ment here, we can easily compensate for slight offsets in the measuring circuits. For instance, we know that the rj temperature has been stabilized somewhere within the range of +160F ± 10F; its exact temperature isn't important because we're going to account for it right here at R13.

By Ohm's Law you can figure out that if R13 is centered, the voltage at its wiper will be about +2.76 volts. It's worth mentioning that this is a good example of how our first class power supply pays off. What would happen if the +15v level changed? Right; we'd have an error in our temperature measurement.

IC3 is connected as a *voltage follower.* It works just like IC2 in that pin 6 is going to do whatever it has to do to set pin 2 equal to pin 3. If pin 3 has been set at +2.76v, what will pin 6 do? Pin 6 will have to rise to +2.76v. So here we have a non-inverting amplifier with a gain of one, also commonly called a *unity gain buffer.*

'So what?' you ask, because on the surface it would appear that IC3 does absolutely nothing. You put +2.76v in and you get +2.76v out. The answer is that IC3 converts a high impedance input to a low impedance output. If R13 is set to the middle of its travel, the resistance from its wiper to ground would be about 35K Ohms, and would vary as we adjusted the pot. This would cause an error in the next circuit, when we add the voltage at R13's wiper to the temperature signal. The buffer IC takes care of this, since its output impedance is always less than one Ohm. And in the next circuit, that will be insignificant.

IC4 is a summing 'amplifier' with two inputs and a gain of one. This circuit is similar in operation to IC2, except that it is an inverting circuit. That means, if you put +1v in, you'll get – 1v out.

One input is the temperature signal from IC2-6. The other is the zeroing voltage from IC3-6. Let's see what happens at – 125F.

IC2-6	+2.76v
IC3-6	–2.76v

As usual, pin 6 of IC4 is going to try to keep pin 2 balanced against pin 3. In this case, pin 3 is grounded through R18. R18 serves only to balance the input resistances for the IC. If you look out from pin 2, you see three 10K resistors connected to pin 6's, low impedance outputs. So effectively, you have three 10K's hooked in parallel to ground, which is about equal to a net 3.33K (10K ÷ 3). To balance things up, we've connected a 3.32K between pin 3 and ground. The reason we do this is because there is a very small current which flows out of pin 2 and pin 3. Its about 70nA. If the input impedances were not balanced, like if we left R18 out, this would cause a small zero offset. In this case it would be about *70nA x 3.33K = 0.23mV,* which is about equal to ± 0.023 degrees. Not much of an error, but we don't have to live with it, so we won't.

So for all practical purposes, pin 3 of IC4 is at zero volts, and so pin 6 is going to set pin 2 to zero volts whenever it can.

If the temperature signal (IC2.-) is +2.76v, it's apparent that the voltage drop across R16 will have to be –2.76v if pin 2 is going to be 0v. The current through R16 is therefore going to be

$$I = \frac{E}{R} = \frac{-2.76v}{10K} = -2.76mA$$

If pin 6 of IC4 wants pin 2 to be 0v, it's going to have to supply this current. Pins 6 of IC2 and IC3 aren't going to help; they're doing their own thing and couldn't care less about pin 2 of IC4. So pin 6 of IC4 will go [–] in order to pull 0.276mA out of IC2-6, through R16 and R17. When we reach this current, we'll have +2.76v on one end of R16 and 2.76v dropped across it in opposite polarity, so the net voltage at it's other end, pin 2, will be zero volts.

But the 0.276mA also flows through R17, from it's pin 2 end into pin 6. So we also have a –2.76v drop here. If pin 2 is 0v, then pin 6 has got to be –2.76v. And that's what it will be, right?

Wrong. The zero voltage is –2.76v. So to keep pin 2 at zero, pin 6 has to put 0.276mA through R15, from it's pin 2 end into IC3-6. In order to do this, IC4-6 would have to go to +2.76v, as we discussed above.

So to zero out both the temperature signal and the zero voltage, IC4-6 will have to go to

to zero E_{temp}	–2.76v
to zero E_{zero}	+2.76v
to zero both	0.00v

At a temperature of +375F, where IC2-6 will be –2.57v, IC4-6 will have to rise to

to zero $E_{temperature}$	+2.57v
to zero E_{zero}	+2.67v
to zero both	+5.33v

So at the output of IC4, we've converted our temperature range to

–125F = 0v
+375F = +5.33v

To get the high end right, we've connected a little adjustable voltage divider between IC4-6 and ground. The adjustment capability lets us correct for any gain errors in IC2 and IC4 due to resistor tolerances. This is where we 'divide by 1.066'. Dividing something by 1.066 is the same as multiplying it times 0.938, so we simply set R19 to tap off 93.8% of the voltage across it and R20.

+5.33v
x0.938
+5.00v

This is then buffered by IC5, which works just like IC3 and is used for the same reason; to provide a low impedance output. So we've now got

−125F = 0v (0% of span)
+375F = +5.00v (100% of span)

All of these IC's have 47pf disc capacitors connected between pins 1 and 8; C4, C5, C6 and C7. These are compensation capacitors. The IC's are good RF amplifiers and without these capacitors they oscillate at high frequency due to stray capacitance in the circuitry.

Failsafe Detector Circuit

The Productsaver is designed primarily as a safety device. As such, it guards against failures and faults in other types of equipment. This means that the Productsaver, itself, must be quite reliable and accurate.

But what if the Productsaver, itself, develops a failure? Should the instrument quietly become inoperative, allowing the system to operate without this protection, it would be a risky situation.

It's not possible to assure that this can't happen. However, each part of the Productsaver's circuitry has been designed in such a way that most types of failures will provide some kind of alarm, or some other form of obvious indication that a fault has developed in the instrument.

A prime area of interest is the thermocouple sensor. It is not an integral part of the instrument, and might be wired over long distances to a remote sensing location. In some cases, scanners or manual thermocouple switches might be used to provide for the monitoring of the temperature at more than one point. What happens if the sensor or its extension wiring becomes broken . . . or if someone forgets to connect it to the instrument?

By looking at the schematic diagram, you can see that the *non-inverting* input of the amplifier circuit, IC2 pin 3, is connected to the sensor, mj, through the reference junction thermocouple (rj). You can also see that if mj becomes open-circuited or is missing altogether, then pin 3 of IC2 will be open-circuited; that is, there will be no path to ground from pin 3.

IC2 is a *non-inverting amplifier.* It is a characteristic of this type of circuit that if its input becomes open, its output will *saturate,* meaning that it will swing to its absolute limit. In this case, the absolute limits are − 15vdc or +15vdc . . . the value of the supply voltages. Accounting for the scaling circuitry, the limits are actually more like ± 13.5v, and the output of IC5 will swing to the positive limit about 99% of the time when a sensor fault develops (a negative swing is also acceptable though).

You will recall that the electronic temperature analog developed by the measuring circuitry is normally 0vdc to +5vdc. Any output less than 0vdc or more than +5vdc is, therefore, bound to generate an alarm, since such outputs would represent temperatures much lower or much higher than the values at the ends of the scale. But this by itself is not good enough.

Most temperature controllers offer either *upscale burn-out* or *downscale burn-out* failsafe protection. In general, this refers to which way the indication will swing in the event of a thermocouple burn-out (broken or missing . . . same thing).

In a heating system, for example, upscale burn-out protection would be used. Thus, a broken sensor would produce a 'much too high' temperature indication, which would keep the heaters turned off until the sensor was fixed.

But in a *bidirectional* temperature control system (heating and cooling), this feature would also turn the cooling system on and keep it on . . . no matter how cold the conditioned area becomes. This is often not very acceptable, even if it is the lesser of two evils.

The Productsaver can be used as a bidirectional temperature controller, or as a temperature limit device in bidirectional control systems. For this reason, special provisions are included which can disable both heating and cooling equipment in the event that its thermocouple sensor becomes open.

This function is provided by IC6 and IC7, which operates a switch composed of transistors Q3 and Q4.

IC6 and IC7 are comparator circuits, not unlike IC1, the reference junction temperature controller. Remember that the inputs are pins 2 and 3, and that the output (pin 6) will saturate (swing to its limit) whenever the voltages at these two inputs are not exactly equal. If pin 3 is positive with respect to pin 2, the output will be at its positive limit . . . and if the voltage on pin 3 is more negative (or less positive) than that at pin 2 the output will swing to its negative limit.

Here again, we have a clamping diode in the circuit, CR2, which establishes the negative output limit at about −0.4vdc while allowing the positive limit to swing to about +13.5vdc.

Notice that the output of IC6 is not used, and that the eighth pin of the IC's are interconnected. This combination is called a *double-ended limit detector.* This name refers to its ability to provide a logical output whenever its input strays beyond either end of a prescribed operating range.

The ends of the operating range are described to the detector by the voltages on pin 2 of IC6 and pin 3 of IC7. Since IC6-2 is connected to ground, one end of the range is obviously 0vdc. IC7-3 is connected to the junction of the resistors R21 and R22. By Ohm's Law you can calculate that the other limit is about +5.075vdc.

The comparator's inputs arrive at pin 3 of IC6 and pin 2 of IC7 . . . it is the temperature analog signal 0vdc to +5vdc. If this signal drops below 0v, IC6 will provide a negative output. Via the interconnected pin 8's, IC6 will force IC7's output to swing negative also. On the other

hand, if the analog voltage rises above +5.075v, then IC7 itself will provide a negative output

From the comparator system only one output is used; pin 6 of IC7. Because of the pin 8 interconnection, a negative output situation at either IC6 or IC7 will force pin 6 of IC7 to go to its negative limit, −0.4vdc. In other words, a negative output at IC6 always predominates over a positive output at IC7.

So what have we seen? We've seen that IC7-6 will be at +13.5vdc whenever the temperature analog is within the range of 0vdc to +5.075vdc, and for inputs outside of this range it will switch to −0.4vdc.

The normal range of the analog signal is 0v to +5v. So whenever the analog signal goes outside of its normal range, the limit detector will provide a − 0.4v output. A broken sensor will cause this, as you learned a few paragraphs above.

The transistor switch, Q3 and Q4, is operated by the output of the limit detector. When the output is +13.5vdc, the transistors will conduct current (*on state*). When the output falls to −0.4vdc, the transistors will be cut off and will not be able to conduct any current.

By inspection of the schematic diagram, you can see that this transistor switch connects the +12v power supply to the red and green alarm lights and relays, I1, K1, I2 and K2. Therefore, in the event of an open temperature sensor, all four of these devices will be off, since the amplifier will slew to its limit causing the failsafe detector to turn off the transistor switch removing power from them. Any heating or cooling equipment connected through these relays will then be turned off, and the yellow alarm circuit will be activated, warning that the fault exists.

The activation of the yellow alarm channel (light, beeper and relay) is provided by the normal limit detection function of the Productsaver. No matter which way the measuring circuit saturates, it will trip either the red or green alarm, since the temperature analog is driven far offscale. This will, concurrently, trip the yellow alarm. Since the red and green lights and relays are disabled, broken sensors provide an unusual *yellow alarm only* indication. This alarm mode itself tells you that the sensor is broken, open or missing.

In the 'failsafed' mode, the meter indication follows the output of the measuring circuit, and the indication pointer will be pinned against its *upscale* stop in 99% of all such cases.

Limit Detector Circuits

The circuits that compare the temperature analog to the high and low limit settings established by the user are IC8 and IC9. IC8 is the high limit detector (red alarm) and IC9 is the low limit detector (green alarm). Beyond having reversed input connections, these two circuits are identical.

Referring again to the schematic diagram, notice the limit adjustments just to the west of IC's 8 and 9. These are the high and low limit adjustments which are accessable to the user through the front panel of the Productsaver. R24 is the high limit adjustment, and its wiper is connected to one input of the high limit comparator, IC8 pin 3. The low limit adjustment, R25, is similarly connected to one input of the low limit comparator, IC9 pin 2.

The other input of these detector circuits, IC8-2 and IC9-3, are provided with temperature information by IC5. This temperature information arrives in the form of the familiar 0v to +5v analog signal, zero representing the low end of the temperature scale and +5v the high end.

The limit adjustments are used to set up reference voltage levels for the limit detectors. The detectors then compare the temperature analog voltage to these upper and lower *trip point* voltage settings. The limit adjustments must therefore be able to cover a range of from 0vdc to +5vdc.

By observation, it's evident that when these adjustments are turned fully counterclockwise, a 0v trip point is established (the dots on the schematic represent the clockwise end of the pots). By Ohm's Law you can calculate that a fully clockwise adjustment will provide a limit setting of just over +5v (+5.172v). So both adjustments cover the full range of the instrument. The adjustment resolution provided is about ± 0.2%, meaning that you can change the limit setting in increments of about one deg. Fahr on instruments having a 500F span.

Remember how comparator circuits work? They simply switch their output voltage (pin 6) between its positive and negative extremes as their input voltages (pins 2 and 3) cross. The polarity of their output will follow the polarity of their pin 3 input as compared with their pin 2 input. For instance, if the voltage on pin 3 is +2.5v and the voltage on pin 2 is +2.6v, then pin 3 is less positive than pin 2 . . . and it can be said that pin 3 is negative with respect to pin 2 . . . so the output, at pin 6, will be at its negative extreme.

Here again, the output extremes are established by clamping diodes connected to pin 8 of these circuits. In this case, a zener diode is used and the two output states are −0.45v and +5.5 volts.

In order to pursue a discussion, assume that the following conditions prevail;

high limit setting:	+3.0v
temperature analog:	+2.5v
low limit setting:	+2.0v

What will the outputs of IC8 and IC9 be; − 0.45 or +5.5 volts?

In the above situation, pin 3 of IC8 will be positive with respect to pin 2 by 0.5 volts, its output at pin 6 will therefore be at its positive extreme. The same can be said of IC9. So both outputs will be at +5.5vdc.

Now, if the temperature signal drops to a value lower than +2.0 volts, pin 3 of IC9 will be negative with respect to its pin 2, and its output will switch from +5.5vdc to – 0.45vdc.

Conversely, if the temperature signal rises above +3.0vdc, the output of IC8 will fall to its negative value.

So here we can begin to discuss voltage levels as having *logical* connotations. At the output of these detector circuits, the voltage will be either +5.5vdc or –0.45vdc, which we'll call *high or low,* respectively. When the temperature is within the set limits, the outputs will be high. When it goes beyond either limit, the output of that detector will be low.

Logic Circuits — General Information

Logic circuits are circuits which are designed to process voltage levels which represent the state or condition of some two-state variable. For example, the temperature is either above or below the high limit setting; that's two states . . . it's either ok or it isn't. At the output of the high limit detector this is represented by a two-state voltage relationship:

too high = –0.45v = 'low'
low = +5.50v = 'high'

The logic circuitry picks up this, and a bunch of other logical inputs, and figures out what types of responses are appropriate for the circumstances in question. This part of the Productsaver's circuitry is not unlike a very simple computer.

When we discuss the operation of logic circuitry, we're only interested in voltage levels to the extent of their being 'high' or 'low'. The general definitions are:

high = +2v to +6v
low = –1v to +1v

In the Productsaver we use DTL type logic circuits or 'chips'. DTL means *Diode-Transistor Logic.* Except for the fact that this determines the above defined voltages' levels, it is not particularly significant.

Notice that there is a 'no-man's land' between the levels of +1v and +2v . . . a one volt margin that's not defined as being 'high' or 'low'. This is done because the threshold, or trip point, for DTL circuitry is about +1.4vdc. It's not good to permit the logic levels to approach this value in their steady state, because noise and temperature variations could then cause these circuits to make mistakes. The one volt *'safety margin'* helps to prevent any uncertainty as to what's high and what's low. In practice, 'low' levels greater than +0.5v are rare, and 'high' levels less than +4.0v are just as rare.

TROUBLESHOOTING NOTE

Replace any device which produces a steady-state logic level between +1.0v and +2.0v; suspect any device that produces a logic level between +0.5v and +4.0v.

We use three types of logic circuits:

The inverter circuit isn't really capable of any powerful logic. It's really just a utility device which simply changes highs to lows, and lows to highs. In other words, its output will always be the opposite of its input. It's sometimes called a NOT circuit . . . for reasons NOT worth going into here, beyond saying that whatever its input is, its output's NOT. It NOT's it's input:

input: 'low'
output: NOT 'low' (. . . but 'high')

. . . so be it. Total confusion, which we can avoid by NOT getting involved with the acronyms and buzz words of the trade.

The NAND gates do provide a logical function:

all inputs high = output low

. . . and for any other condition their output will be high. This applies to all NAND gates, no matter how many inputs they have . . . one or one hundred. For instance, if only one of the device's two or three inputs are low, it's output will be high, or if they're all low, its output will be high. Its output will be low only when all of its inputs are high.

Reconsider the inverter circuit. Isn't the same thing true of it? Even though it has only one input, it does conform to the NAND convention:

all inputs high = output low
all input(s) low = output high

So there you have the key to understanding how the logic system in the Productsaver operates, and to troubleshooting in this part of the circuit when faults are suspected.

Our discussion of the logic circuits in the following paragraphs will be limited to a general functional overview. To go through each stage of this circuitry discussing 'highs' and 'lows' would become quite burdensome, and it's almost impossible to follow this type of treatment in test form. It gets so confusing trying to remember what's high and what's low, that the whole exercise soon becomes meaningless. The operation of these circuits is quite simple, and once you memorize the above 'key', you'll have no difficulty in doing stage by stage evaluations for yourself.

The logic circuitry may be divided into four parts:

*Meter & Reset Logic
*High Limit Logic
*Low Limit Logic
*Yellow Limit Logic

Meter & Reset Logic

This part of the circuit has four inputs, each of which has either two or four states.

Switches S1 and S2 are the red and green push-button switches on the front of the instrument. When these switches are closed (depressed), the 'low' signal resulting represents that the user is either trying to reset an alarm, or desires to observe the alarm setting. When open, a 'high' condition is provided via resistors R36 and R37, which are connected to the +5v supply. This 'high' logical input signifies that the user is not attempting to reset an alarm or observe a set point.

Switches S4 and S5 are the reset mode switches inside the instrument. With these switches the user can set the instrument for (1) automatic reset, (2) manual reset with automatic start-up, or (3) manual reset with alarms at start-up (power failure detection feature). These modes may be separately selected for the red and green alarm channels.

In position 1, these switches connect directly to the +5v supply, thus providing a 'high' indication. Since this is the 'automatic reset' position, it's evident that a 'high' output from these switches represents a 'reset' command . . . in this case, a constant reset instruction.

Since this is true, it's evident that the 'low' logic level provided at position 3 means 'don't reset'. If you trace through the IC15 inverter stages, you'll find that a 'low' level at pins 12 and 10 represent a 'reset' instruction.

Notice that pins 2 and 12, also pins 6 and 10, are wired together. When DTL outputs are connected like this, a 'low' level from any one of the outputs will prevail.

Going back to S4 and S5, position 2 provides a 'high' level during the first ten seconds after power is applied to the instrument, and a 'low' level thereafter. So for the first ten seconds, the instrument is set for automatic reset, then it reverts to manual reset operation. This feature eliminates the alarms that would otherwise occur when the system is turned on — so long as the temperature is within limits at start-up. Start-up alarms can be a nuisance, especially for heavily protected equipment. In this position, momentary power failures will also be followed by automatic start-up.

We've seen that two of the outputs from this part of the logic circuitry are reset control lines:

Red reset control output: IC15-12
Grn reset control output: IC15-10

There are three other outputs which control the meter on the front of the instrument. The meter is used to display the temperature, the high limit setting and the low limit setting. The three meter control lines are:

high limit display: IC15-4
temperature display: IC19-2
low limit display: IC15-8

A 'high' level on any one of these outputs is a command to display that particular parameters. Thus, if you depress S1 on the front of the instrument, IC15-4 will go high, instructing the meter switching circuit to display the high limit setting.

You can trace through the various stages involved and see that only one of these three outputs will be high at any one time, unless S1 and S2 are depressed simultaneously. This is a fault condition which the meter switching circuits will refuse to acknowledge. If neither switch is depressed, IC19-2 will be high, which instructs that the temperature be displayed; this is the normal condition.

Auto-Start and Meter Switching Circuits

Before going to the remaining sections of the logic circuitry, let's cover these two associates of the *Meter and Reset Logic* section.

The auto-start circuit is a simple delay circuit. IC14 serves as a comparator, or limit detector, very similar to IC8 and IC9, which you are now familiar with. The reference for IC14 is provided by a voltage divider, resistors R34 and R35. By Ohm's Law you can compute that the reference voltage, or 'trip point', is about +11.3vdc. This is connected to pin 3 of IC14.

Pin 2 of IC14 is connected to an RC network, R32 and C16, through an input protection resistor R33 (prevents C16 from discharging heavily into this input).

When the instrument is off, C16 will discharge completely. Thus when it is turned on, the voltage across C16 will be zero, so pin 2 will feel a potential of −15vdc at this first instant after turn on. But with power now on, C16 begins to charge in a positive direction, with its charging current being restricted by R32.

The rate at which it charges is called the time constant of this RC network:

$$TC = RC$$
$$= 1\ \text{Meg} \times 4.7\text{uf}$$
$$= 4.7\ \text{seconds}$$

In two time constants, the capacitor in an RC network will charge to 87% of the applied voltage. In this case, the applied voltage is 30 volts (−15v + 15v = 30v). So, in about 9.4 seconds, C16 will have charged to about 26.3 volts. At this time, the voltage at pin 2 with respect to ground is . . .

$$26.3\text{v} - 15\text{v} = +11.3\text{v}$$

. . . the same as the reference voltage at pin 3. Prior to this instant, pin 3 is positive with respect to pin 2, so the output, pin 6, will be at its positive limit. Just past this instant, as C16 continues to charge, pin 2 will become positive with respect to pin 3, so the output will reverse to its negative limit.

Clamping diode CR5 sets the output limits at:

'high' = +5.5v
'low' = −0.4v

So for the first ten seconds of operation, a 'high' level is provided, and we've seen that this will be interpreted as a reset instruction. Following that, a 'low' level output from this circuit causes the instrument to revert to manual reset operation.

The meter switching circuit is a hybrid affair which combines both logic and analog functions.

IC10 and IC11 are known as *Analog Gates*; electronic relays, if you will. Each IC contains two switches, as shown on the schematic diagram. These switches close when a 'high' logic level is applied to their respective control terminals, pins 9 and 13. A 'low' level causes them to open. Also, pin 10 is an 'inhibit' input. A 'high' level applied to this pin causes both switches to open, no matter what their inputs are.

These switches receive their instructions from the Meter and Reset Logic, as explained in the previous section. You can correlate these instructions with the various inputs (pins 14 and 8), in order to see how the set point and temperature signals are switched into the buffer circuit IC12. You will note that pin 9 of IC11 is grounded; this switch never operates even though it appears to be usefully connected. Also note that if both S1 and S2 are depressed at the same time, both IC10 and IC11 will be inhibited; all switches open.

IC12 is a buffer circuit. As you've already learned, this type of circuit produces an output which is identical to its input. Its purpose is to protect its input signal's source from the effects of current loading, and thereby preserve the accuracy of that source. When its input is open (all switches open) this circuit will automatically drive its output to a negative limit. This action pins the meter pointer against its downscale stop when both S1 and S2 are depressed at the same time.

M1 is the meter on the front of the instrument. Although fitted with a temperature scale, this meter actually has a 0mA to 1.0mA movement. Recalling that our temperature analog signal has a 0v to +5v calibration, it's evident that the total resistance in the meter circuit will have to be . . .

$$R = E \div I$$
$$= 5v \div 1.0mA$$
$$= 5K$$

. . . This value is set by R26 and R27. R26 is the electrical span adjustment for the meter itself. The meter is equipped with its own mechanical zero adjustment.

So you see we have two zero and two span adjustments in the Productsaver. This is done because we have several circuits that require a precision voltage analog of temperature, and we did not wish to degrade that signal as necessary to accommodate the fairly large tolerances which accrue in the indicating circuitry. By the same token, it's very important that you not adjust R13 and R19 to properly position M1. Adjust those two to provide a precision analog voltage, then use M1's own adjustments to correct its indicating errors, if any.

Red and Green Limit Logic

The High Limit (Red) and Low Limit (Grn) logic circuits are identical, and pleasurably simple. This being the case, we'll discuss only the High Limit section, with the understanding that the discussion is almost directly transferrable to the Low Limit side.

The High Limit logic circuitry has two inputs and three outputs. The inputs are (1) the 'limit exceeded' logic signal from IC8-6 and (2) the 'reset'logic signal from IC15-12. The outputs are (1) an 'alarm status' logic signal from IC19-8, (2) visual alarm I1 and (3) alarm contact K1.

limit input: 'low' when beyond the limit
reset input: 'low' when instructed to reset the alarm

visual alarm output: 'high' or **ON** when beyond the limit
alarm contact: 'low' or **OPEN** when beyond the limit
alarm status output: 'low' when beyond the limit

Please refer to the two-gate network just northwest of capacitor C17 on the schematic diagram (IC16). This is a latching circuit, and we will go through it briefly.

Assume that the temperature is below the high limit setting, and that any prior alarm has been reset:

IC16-1: high —
IC16-2: high — = IC16-3: low

and,

IC16-4: low —
IC16-5: high — = IC16-6: high

IC16-3 is the output of the latch. As you see here, this output will be low during 'normal' conditions.

You will soon see how we know, at this point, that IC16-2 is high. Don't concern yourself with that just yet. Now suppose that the temperature passed the high limit. This causes IC8-6 to fall to the 'low' condition, then:

IC16-1: low —
IC16-2: high — = IC16-3: high

and,

IC16-4: high —
IC16-5: high — = IC16-6: low

leaving,

IC16-1: low —
IC16-2: low — = IC16-3: high

Now you push S1, the red reset push-button:

IC16-4: high —
IC16-5: low — = IC16-6: high

and,

IC16-1: low —
IC16-2: high — = IC16-3: high

Now release S1:

IC16-4: high —
IC16-5: high — = IC16-6: low

and,

IC16-1: low —
IC16-2: low — = IC16-3: high

Here you see that the output of the latch goes high when the limit is exceeded, and that the reset input has no effect on its output so long as the temperature is beyond the limit.

Now the temperature comes back to a value less than the limit setting, so IC8-6 goes to the high condition:

IC16-1: high —
IC16-2: low — = IC16-3: high

Note that this didn't affect the lower side of the latch, and that the latch output remains high even though the temperature is now within limits. This clearly demonstrates the latching function of this circuit. Now push the reset button, to provide:

IC16-4: high —
IC16-5: low — = IC16-6: high

and,

IC16-1: high —
IC16-2: high — = IC16-3: low

leaving,

IC16-4: low —
IC16-5: high — = IC16-6: high

. . . when the reset switch is released. As you can see, the output is now latched in the low state.

Capacitor C17 has two reasons for being. It guards the latch circuit against high frequency electrical interference which would otherwise cause it to randomly generate or reset alarms in an illogical manner. It also assures that the latch will start in the alarm mode when power is first applied by slowing the pull-up of IC16-2. This is required for reliable 'power failure detection' when S4 has been set at position 1.

Transistors Q5 and Q6 act as an electronic switch, just like Q3 and Q4 which we discussed earlier. A high logic level applied to R39 turns Q5 and Q6 on, allowing current to flow through the red alarm light I1. You will recall that a high output is provided from the latch circuit during alarm conditions. Resistor R39 limits the current used to operate the transistor switch to a reasonably small value. Resistor R40 allows a small current to flow through the lamp when the switch is off. This keeps its filament warm, and thereby extends its useful life by preventing serious thermal shock each time it is turned on.

The latch output is inverted at IC19-8. Hence, the alarm relay will be turned off (contacts open), when the alarm condition occurs. This is a failsafe setup. Any equipment interlocked through these contacts will be disabled when power is removed from the Productsaver, or if the relay fails to mechanically operate. Diode CR7 prevents inductive kick-back when switch Q7-Q8 opens. Without CR7, the relay coil would be capable of generating spikes greater than 1,000 volts. Capacitor C19 prevents oscillation in this circuit as the relay is being turned on.

Notice that the red indicator light can be connected to operate with the relay if desired. This is desirable when the Productsaver is being used as a temperature controller instead of an alarm device.

Finally, note that the 'alarm status output' is the inverted latch output, taken from IC19-8:

alarm on: low
alarm off: high

Yellow Limit Logic

The yellow limit logic circuit, due east of IC13, has three inputs and three outputs. The three inputs are (1 and 2) the red and green alarm status outputs and (3) the yellow push-button switch, S3. The three outputs consist of the yellow alarm light, alarm contact, and beeper.

The 'alarm status' inputs, connected to IC17 pins 3 and 5 (ignore pin 4), actuate the yellow alarm logic. There will be a yellow alarm whenever there is a red or green alarm, and the yellow alarm will reset with the red or green circuits. Notice that the yellow logic inputs can, instead, be connected directly to the limit detectors IC8 and IC9. With this connection it is possible to provide automatic reset on the yellow alarm, with manual reset on the red and green alarms. This is sometimes useful when the yellow alarm is wired to operate remote alarms in guardposts, outer offices, etc.

IC13 is a square wave generator circuit. It provides the signal that causes the yellow light to flash on and off, and the beeper to 'beep'. Observe that this circuit is very similar to IC14, the auto-start delay circuit, except in one respect; R29 is connected to the output of IC13 at pin 6.

Assume that the output at IC13-6 is at the high state, which is clamped at +5.5v by CR5. This means that the charge on capacitor C14 must be less positive than the voltage drop across R30. By Ohm's Law you may calculate that the voltage drop across R30, which is applied to IC13-3, is +4.78 volts. This is equal to about 86% of the voltage applied to the RC network R28 and C14. From our discussion of IC14, we recall that the charge on the capacitor will arrive at the 86% level in two time constants, and in this case the time constant is

TC = R x C
= 1 Meg x 0.1mfd
= 0.1 second

So, in about 0.2 seconds the output of IC13 will switch to its negative limit, which is clamped at -0.45 volts.

At this time, the reference voltage at IC13-3 changes to about -0.39v and the applied voltage at the RC network is equal to the combination of the capacitor charge and the voltage at IC13-6, about 5.23 volts. So C14 will have to discharge through a range of 5.17 volts in order to get down to the -0.39v reference level. This 5.17 figure is about 96% of 5.23, the effective applied voltage, so this discharge process is going to take about three time constants, or about 0.3 seconds. After this time has elapsed, the output of IC13 will return to its high state once again.

So one complete cycle takes 0.5 seconds, with the result that the pulse rate produced at this circuit is about two pulses per second. As can be seen, this sequencing will go on forever, producing a continuous pulse train to flash I3 and beep the beeper. This pulse train is connected to the yellow alarm logic at IC17-9 and IC18-9.

We will not laboriously trace logic levels through the yellow logic system for reasons stated earlier. You may wish to do this as an interesting exercise. Otherwise, let it suffice to understand that when this circuit first enters the alarm condition, I1 and A1 will be operated in a pulse manner (2Hz) and the yellow alarm contacts will open and remain open.

Then, when the yellow push-button, S3, is depressed, A1 will be latched off and I1 will be latched on, with K3 remaining off. This condition will then prevail until the alarm is reset manually or automatically, as the case may be. At that time, K1 will be turned on, I1 will be turned off and A1 will remain off.

Notice the optional connections provided for K3's transistor switch. When connected to IC19-6, K3 will operate with the beeper. This connection is sometimes preferred when using K3 to operate remote alarm devices. When connected to IC17-8, K3 operates inverse to A1. This is about the same except that with this connection, the remote alarm device will operate when Productsaver power is lost as well as during alarm conditions. With this connection the remote device should be a light rather than a bell or buzzer since it will operate even when the Productsaver protected equipment is intentionally turned off.

All the relay contacts are wired for double-break operation, as shown on the schematic diagram. This helps to extinguish arcs faster, thus helping to extend their useful life.

This wraps up our study of the Productsaver circuitry. As you have seen, it's not really very formidable. If you've studied this section carefully, you now know the purpose of every item shown on the schematic diagram. With this knowledge, troubleshooting is simply a matter of finding which of these items is not doing its part.

SPARE PARTS KIT

We do not recommend that you keep a kit of spare parts on hand, because our experience indicates that the nature of failures is quite random. This being the case, it is unlikely that you would have the required replacement part unless you were to stock a fairly large number of items.

If, for reasons of your own, you do wish to order spare parts, refer to the *Suggested Spare Parts* listing which follows the *Symbolic Parts List.*

FACTORY SERVICE

By virtue of the small size/low cost nature of most ACS products, field service is not generally offered. In lieu of field service, we have developed an especially effective factory service capability.

Units which develop defects in the field may be shipped without prior authorization to our factory in Holland, Michigan for repairs. Such units are treated on an 'inspect and repair as necessary basis' by fully qualified production personnel — the same people who originally built the item in most cases. Returned units are typically repaired and reshipped to the user within twenty-four hours, unless 'intermittent' types of failures require longer observation periods, or week ends or holidays intervene.

Warranty service is provided without charge, and non-warranty service is done on a time + material basis, at the rates prevailing at the time that the service is performed.

Returned items should be very carefully packed in order to avoid damage in shipment. Please enclose a purchase order, or other authorizing document, with the shipment. Be sure to specify:

(1) warranty service claimed, or not
(2) your full return address
(3) the specific nature of the defect
(4) the name of someone at your plant who may be contacted for information

Please address the shipment and any related paperwork to:

Thermotron Corporation
ACS Factory Service
Kollen Park Drive
Holland, Michigan 49423

GUARANTEE

Our products are guaranteed to meet or exceed published specifications, and to perform their designed function in a reliable manner. We will repair or replace any unit that fails to do so.

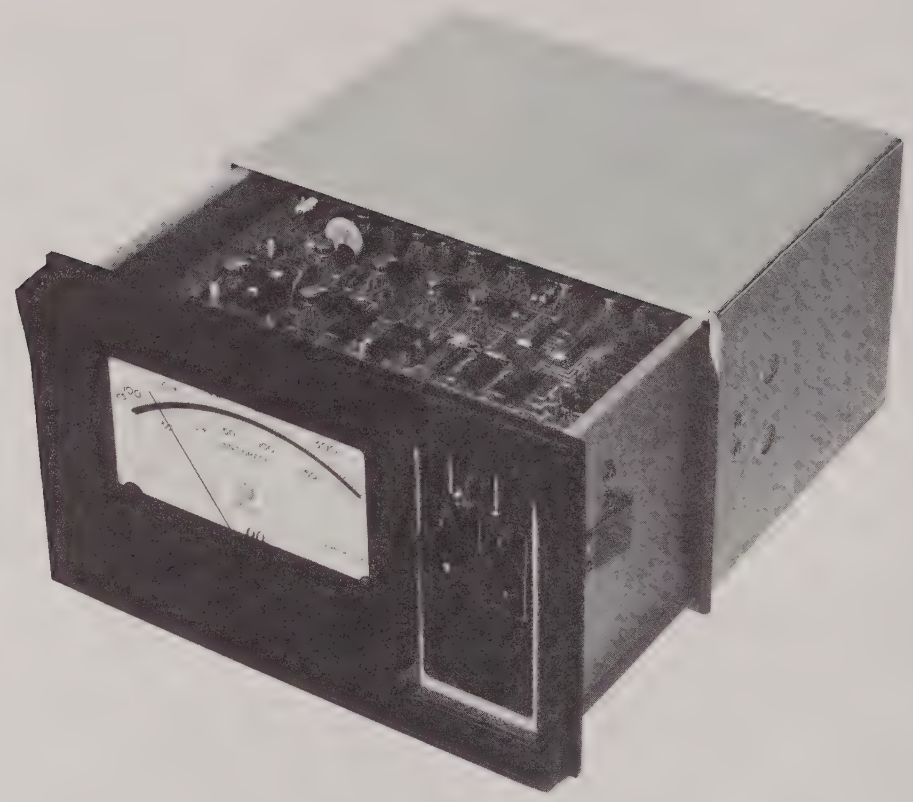
During the first thirty days following shipment from our plant, you may return any defective units to our plant for corrective action. This will be handled at our expense entirely, including any related shipping costs . . . and **excluding** any costs that you might incure within your organization. The decision to repair or replace will be our prerogative.

During the first 365 days following shipment from our plant, the same arrangement will apply, **except** that you will be expected to pay for any related shipping costs to and from our plant in Holland, Michigan U. S. A.

After the 365 day period has expired, you may return any defective units to our plant for corrective action. This will be handled at your expense entirely, including any related shipping costs. Repair costs will be based upon time rates and material prices as they exist at the time that the repair is accomplished.

Please refer to the Service section, above, for shipping instructions.

This guarantee does not cover shipping damage, or damage caused by handling, misuse or abuse, whether accidental or intentional.



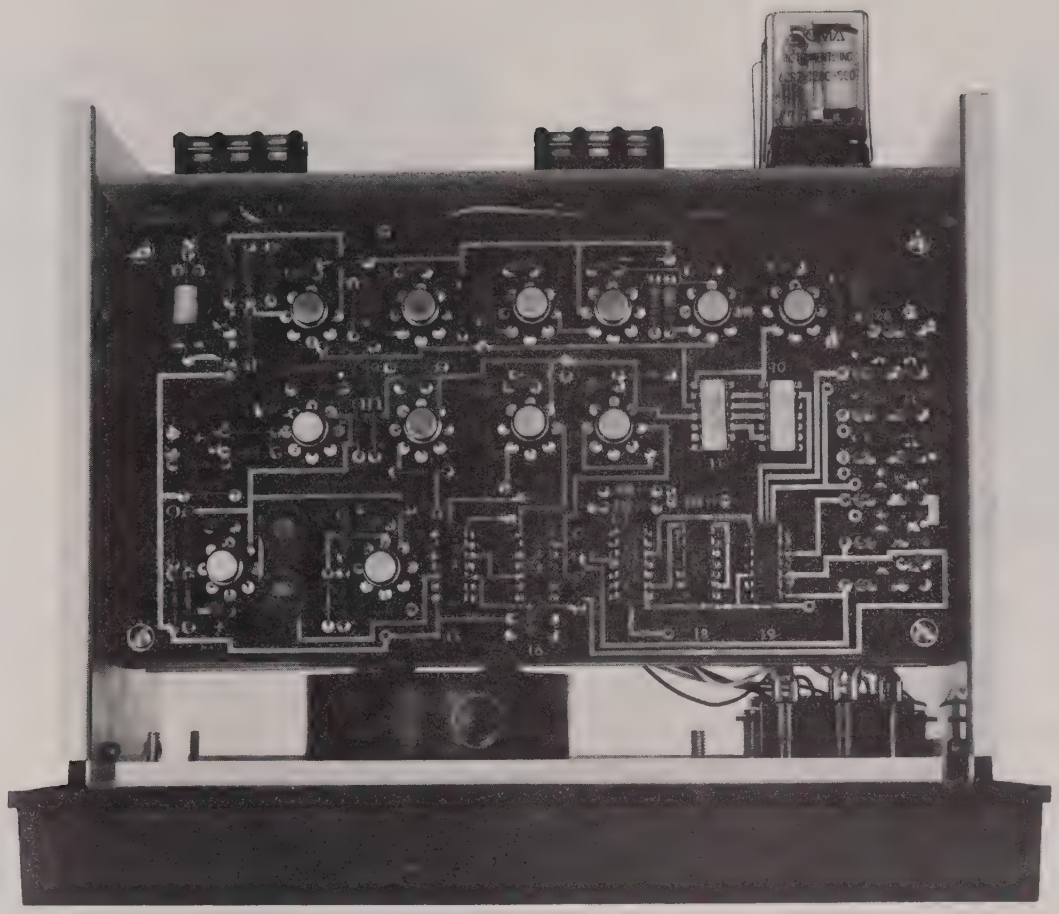
Productsaver
Model 012005

IISS NO.	DESCRIPTION	QTY
041002	BRACKET, Mounting P'saver	2
048009[1]	PCB ASSY, Main P'saver	1
048010[1]	PCB ASSY., Power P'saver	1
048011[1]	PCB ASSY., Set Point P'saver	1
048012[1]	PCB ASSY., Terminal P'saver	1
102001	SWITCH, Lited PB (Red)	1
102002	SWITCH, Lited PB (Grn)	1
102003	SWITCH, Lited PB (Ylw)	1
112003[2]	RELAY, 2P2T 5A 12v	3
123004[3]	METER, Temp –125F/+375F	1
124001	ANNUNCIATOR, Audible	1
196017	WIRE ASSY., Gnd 3½"	1
205006	PANEL, Annunciator	1
251008	GROMMET STRIP, .040/.062	4.13ft.
263001	COVER, Safety Int P'saver	1
263002	COVER, Safety Ext P'saver	1
271005	SCREW, Bdr Hd 4-40x.375	16
271007	SCREW, Bdr Hd 4-40x.625	2
271028	SCREW, Sheet Mtl Type A No. 6x.500	2
271029	BOLT, Rnd Hd 5/16-18x2"	2
272003	WASHER, Flat No. 4	10
272004	WASHER, Flat No. 6	6
273003	LOCKWASHER, Split No. 6	6
273007	LOCKWASHER, Int. No. 4	18
273011	LOCKWASHER, Int Inst .375"	3
274003	NUT, Hex No. 6	4
274006	NUT, Knurled Inst .375-32	3
274007	NUT, Knurled Sonalert 1.125-24	1
274008	NUT, Hex .3125-18	2
275003[2]	RETAINER CLIP, Relay 2P2T	3
276001	POP RIVET, .125 x .125	9
276002	POP RIVET, .1562 x .250	4
279002	SPACER, No. 6 x .375	2
279005	THREDSPACER, 4-40 x .250	18
351005	CABINET ASSY., P'saver	1
352007	CHASSIS, P'saver	1
353002	BEZEL, P'saver	1
354006	BRACKET, PCB P'saver	2
354001	CLIP, Detent P'saver	4
451011	USER'S MANUAL, P'saver	1

[1] Separate parts breakdown provided for these sub-assemblies.

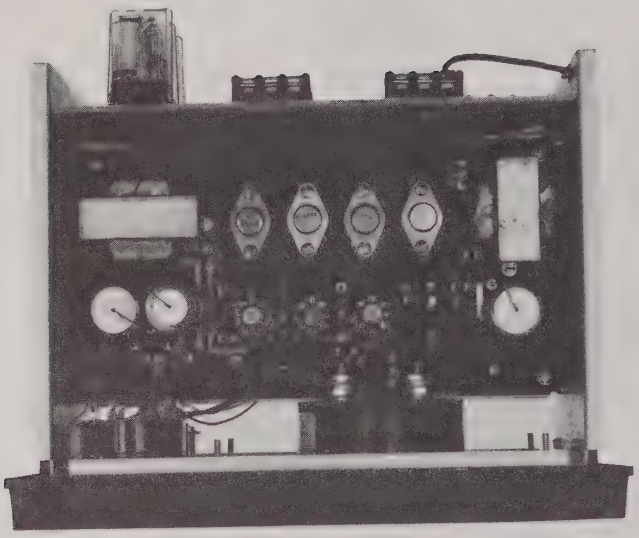
[2] Order retainer clip 275003 when ordering relays to assure correct fit.

[3] Standard Range. Scales are interchangable.



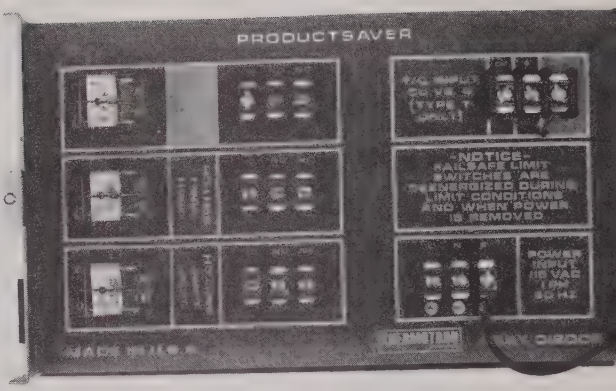
PCB ASSY., Main P'saver
048009

IISS NO.	DESCRIPTION	QTY
051129	RESISTOR, Comp 560 Ohms ½w 5%	3
052101	RESISTOR, Film 10 Ohms ¼w 1%	2
052309	1.21K	2
052339	2.49K	2
052351	3.32K	1
052355	3.65K	1
052366	4.75K	2
052368	4.99K	4
052396	9.76K	1
052401	10.0K	11
052406	11.3K	2
052411	12.7K	3
052451	33.2K	1
052475	59.0K	1
052518	150K	1
052571	536K	1
052601	1.0 Meg	3
054002	POTENTIOMETER, Trim 500 Ohms 25t	1
054004	5K	2
062001	CAPACITOR, Disc 47pf 1kv	8
062003	0.1uf 100v	2
062004	0.01uf 100v	4
063002	CAPACITOR, Tant 1.0uf 50v	7
063003	CAPACITOR, Tant 4.7uf 50v	1
081007	DIODE, Rect 1N4002	2
081014	DIODE, Zen 1N4687	4
083005	TRANSISTOR, NPN 2N3391	15
091001	I.C., 4x2 Gate DM946N	2
091002	I.C., Hex Inv DM936N	2
091003	I.C., 3x3 Gate DM962N	1
093001	I.C., Op Amp LM301AH	11
093002	I.C., Op Amp LM308AH	1
093008	I.C., Analog Gate AH0152CD	2
103002	SWITCH, Rot PCB 4-Pos	2
169001	RJC ASSY., T-240	1



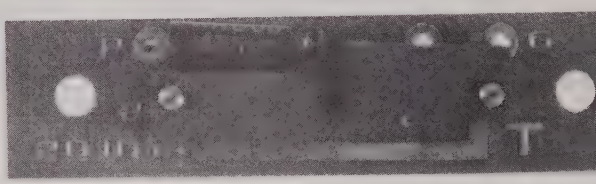
PCB ASSY., Power Supply P'saver 048010

IISS NO.	DESCRIPTION	QTY
051784	RESISTOR, WW 3.0 Ohms 2w 5%	1
051785	5.1 Ohms	1
052388	RESISTOR, Film 2.43K ¼w 1%	1
052348	3.09K	1
052368	4.99K	1
052390	8.45K	1
052401	10.0K	1
052411	12.7K	1
054003	POTENTIOMETER, Trim 2.0K 25t	3
062001	CAPACITOR, Disc 47pf 1kv	2
063002	CAPACITOR, Tant 1.0uf 50v	2
063003	4.7uf 50v	1
064002	CAPACITOR, Elect 250uf 50v	3
071001	TRANSFORMER, Pwr 115v/42vct@.1A	1
071005	115v/17vct@.15A	1
081007	DIODE, Rect 1N4002	6
083003	TRANSISTOR, PNP 2N4898	3
083004	TRANSISTOR, NPN 2N4910	1
083005	2N3391	1
093003	I.C., Pos Reg LM305AH	2
093004	I.C., Neg Reg LM304H	1
233006	HEAT SINK, TO-66	4
271005	SCREW, Bdr Hd 4-40x.375	8
273007	LOCKWASHER, Int. No.4	8
274002	NUT, Hex No. 4	8



PCB ASSY., Terminal P'saver 048012

IISS NO.	DESCRIPTION	QTY
081004	DIODE, Rect 1N4004	3
175001	SOCKET, Relay 2P2T	3
176003	TERMINAL BLOCK, 3-w EPC	5



PCB ASSY., Set Point P'saver 048011

IISS NO.	DESCRIPTION	QT
052366	RESISTOR, Film 4.75K ¼w 1%	
054004	POTENTIOMETER, Trim 5K 25t	

SYMBOLIC PARTS LIST

ymbol	List	Type	Spec	Number
A1	005		beeper	124001
1	009	CM	47pf	062001
2	009	CM	0.1uf	062003
C3	009	CT	1.0uf	063002
4	009	CM	47pf	062001
5	009	CM	47pf	062001
C6	009	CM	47pf	062001
C7	009	CM	47pf	062001
8	009	CM	0.01uf	062004
9	009	CM	0.01uf	062004
C10	009	CM	0.01uf	062004
11	009	CM	0.01uf	062004
12	009	CM	47pf	062001
C13	009	CM	47pf	062001
C14	009	CM	0.1uf	062003
15	009	CM	47pf	062001
16	009	CT	4.7uf	063003
C17	009	CT	1.0uf	063002
18	009	CT	1.0uf	063002
19	009	CT	1.0uf	063002
C20	009	CT	1.0uf	063002
C21	009	CT	1.0uf	063002
22	010	CE	250uf	064002
C23	010	CE	250uf	064002
C24	010	CM	47pf	062001
25	010	CM	47pf	062001
26	010	CT	1.0uf	063002
C27	010	CT	1.0uf	063002
28	010	CT	4.7uf	063003
29	010	CE	250uf	064002
C30	009	CT	1.0uf	063002
R1	009	DR	IN4002	081007
R2	009	DR	IN4002	081007
CR3	009	DZ	IN4687	081014
CR4	009	DZ	IN4687	081014
R5	009	DZ	IN4687	081014
R6	009	DZ	IN4687	081014
CR7	012	DR	IN4004	081004
R8	012	DR	IN4004	081004
R9	012	DR	IN4004	081004
CR10	010	DR	IN4002	081007
CR11	010	DR	IN4002	081007
R12	010	DR	IN4002	081007
CR13	010	DR	IN4002	081007
1	005	(see S1)		
2	005	(see S2)		
3	005	(see S3)		

IC1	009	OA	LM301AH	093001
IC2	009	OA	LM308AH	093002
IC3	009	OA	LM301AH	093001
IC4	009	OA	LM301AH	093001
IC5	009	OA	LM301AH	093001
IC6	009	OA	LM301AH	093001
IC7	009	OA	LM301AH	093001
IC8	009	OA	LM301AH	093001
IC9	009	OA	LM301AH	093001
IC10	009	AG	LH0152CD	093008
IC11	009	AG	LH0152CD	093008
IC12	009	OA	LM301AH	093001
IC13	009	OA	LM301AH	093001
IC14	009	OA	LM301AH	093001
IC15	009	HI	DM936N	091002
IC16	009	PN	DM946N	091001
IC17	009	NT	DM962N	091003
IC18	009	QN	DM946N	091001
IC19	009	HI	DM936N	091002
IC20	010	PR	LM305AH	
IC21	010	PR	LM305AH	
IC22	010	NR	LM305AH	
K1	005	12v	2P2T	112003
K2	005	12v	2P2T	112003
K3	005	12v	2P2T	112003
M1	005		meter	123004
Q1	009	TN	2N3391	083005
Q2	009	TN	2N3391	083005
Q3	010	TN	2N3391	083005
Q4	010	TN	1N4910	083004
Q5	009	TN	2N3391	083005
Q6	009	TN	2N3391	083005
Q7	009	TN	2N3391	083005
Q8	009	TN	2N3391	083005
Q9	009	TN	2N3391	083005
Q10	009	TN	2N3391	083005
Q11	009	TN	2N3391	083005
Q12	009	TN	2N3391	083005
Q13	009	TN	2N3391	083005
Q14	009	TN	2N3391	083005
Q15	009	TN	2N3391	083005
Q16	009	TN	2N3391	083005
Q17	009	TN	2N3391	083005
Q18	010	TP	2N4898	083003
Q19	010	TP	2N4898	083003
Q20	010	TP	2N4898	083003

R1	009	RF	12.7K	052411
R2	009	RF	12.7K	052411
R3	009	RF	12.7K	052411
R4	009	(see rjc)		
R5	009	RF	10K	052401
R6	009	(see rjc)		
R7	009	RF	1.21K	052309
R8	009	RF	536K	052571
R9	009	RF	1.21K	052309
R10	009	RF	2.49K	052339
R11	009	RF	2.49K	052339
R12	009	RF	59.0K	052475
R13	009	PT	5K 25t/w	054004
R14	009	RF	11.3K	052406
R15	009	RF	10.0K	052401
R16	009	RF	10.0K	052401
R17	009	RF	10.0K	052401
R18	009	RF	3.32K	052351
R19	009	PT	5K 25t/w	054004
R20	009	RF	33.2K	052451
R21	009	RF	9.76K	052396
R22	009	RF	4.99K	052368
R23	011	RF	4.75	052366
R24	011	PT	5K 25t/w	054004
R25	011	PT	5K 25t/w	054004
R26	009	PT	500 25t/w	054002
R27	009	RF	4.75K	052366
R28	009	RF	1 Meg	052601
R29	009	RF	150K	052518
R30	009	RF	1 Meg	052601
R31		(none)		
R32	009	RF	1 Meg	052601
R33	009	RF	4.75K	052366
R34	009	RF	3.65K	052355
R35	009	RF	11.3K	052406
R36	009	RF	4.99K	052368
R37	009	RF	4.99K	052368
R38	0	RF	10.0K	052401
R39	009	RF	10.0K	052401
R40	009	RC	560	051129
R41	009	RF	10.0K	052401
R42	009	RF	10.0K	052401
R43	009	RC	560	051129
R44	009	RF	10.0K	052401
R45	009	RF	4.99K	052368
R46	009	RF	10.0K	052401
R47	009	RF	10.0K	052401
R48	009	RF	10.0K	052401
R49	009	RC	560	051129
R50	010	RW	3.0	051784
R51	010	RF	4.99K	052368
R52	010	PT	2K 25t/w	054003
R53	010	RF	3.09K	052348
R54	010	RF	12.7K	052411
R55	010	PT	2K 25t/w	054003
R56	010	RF	8.45K	052390
R57	010	PT	2K25t/w	054003
R58	010	RF	2.43K	052388
R59	010	RW	5.1	051785
R60	009	RF	10.0	052101
R61	009	RF	10.0	052101
RJC	009		T-240	169001
S1	005	SP	red	102001
S2	005	SP	grn	102001
S3	005	SP	ylw	102001
S4	009	SR	red	103002
S5	009	SR	grn	103002
T1	010		115/42	071001
T2	010		115/17	071005

KEY:

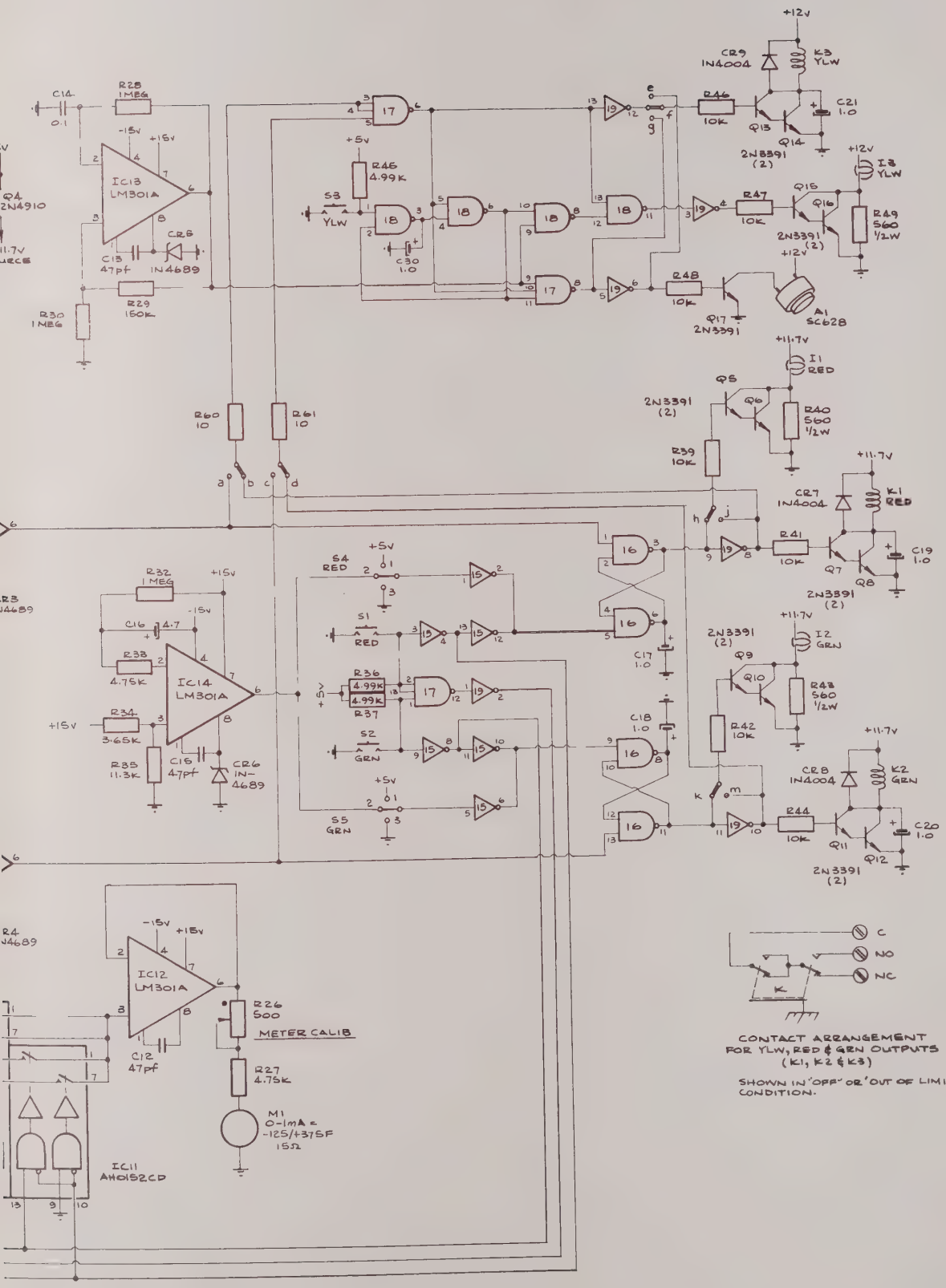
A	Audible Device
AG	Analog Gate
C	Capacitor
CE	Capacitor, electrolytic
CM	Capacitor, mica (disc)
CP	Capacitor, polyethylene
CR	Diode
CT	Capacitor, tantalum
DR	Diode, rectifier
DZ	Diode, zener
HI	Hex Inverter
I	Indicator (lamp)
K	Relay
M	Meter
NR	Negative Regulator
NT	3-Input NAND Gate
OA	Operational Amplifier
PR	Positive Regulator
PT	Potentiometer, trimmer
Q	Transistor
QN	Quad NAND Gate
R	Resistor
RC	Resistor, composition
RF	Resistor, film
RJC	Reference junction compensator
RW	Resistor, wire wound
S	Switch
SP	Push-button Switch
SR	Rotary Switch
T	Transformer
TN	Transistor, NPN
TP	Transistor, PNP

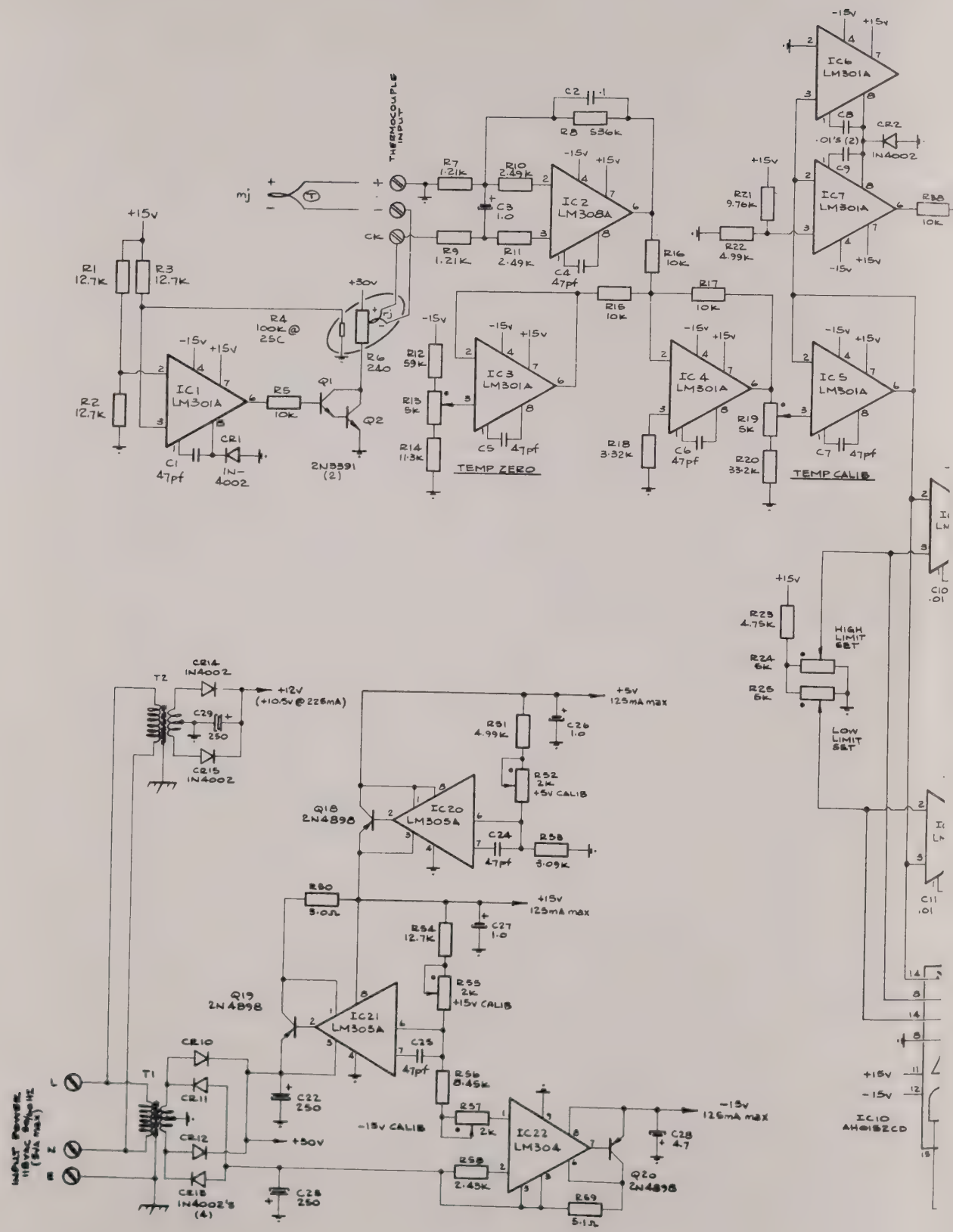
SUGGESTED SPARE PARTS

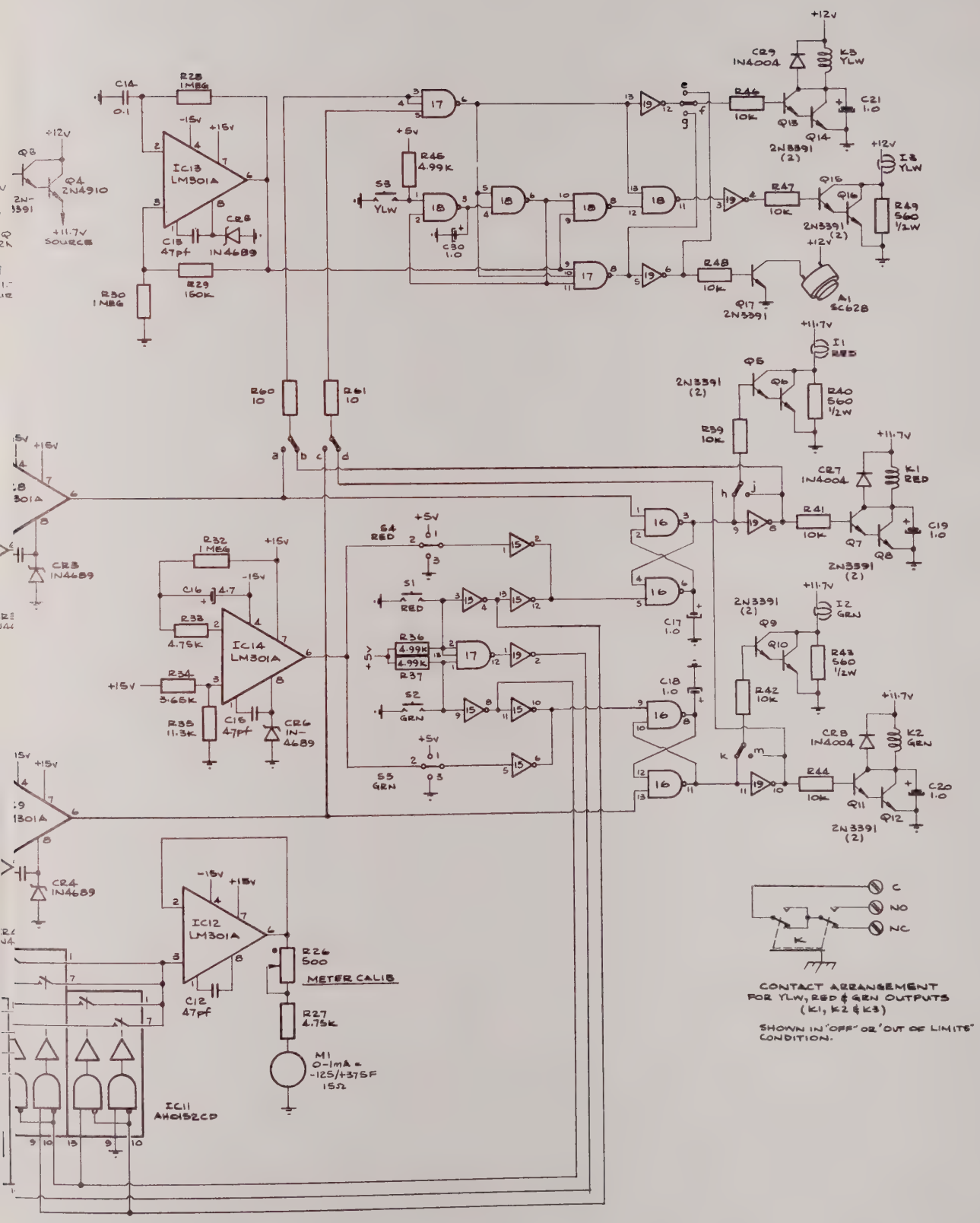
063002	Capacitor, Tant 1.0uf 50v	2
063003	4.7uf 50v	2
081007	Diode, Rect IN4002	4
081014	Diode, Zen IN4687	1
083003	Transistor, PNP 2N4898	1
083005	NPN 2N3391	4
091002	I.C., Hex Inv DM936N	1
093001	OP Amp LM301AH	2
093003	Pos Reg LM305AH	1
103002	Switch, Rot PCB 4-Pos	2
112003	Relay, 2P2T 5A 12v	1
169001	RJC ASSY, T-240	1
175001	Socket, Relay 2P2T	1
176003	Terminal Block, 3-w EPC	1
451011	User's Manual, P'saver	1

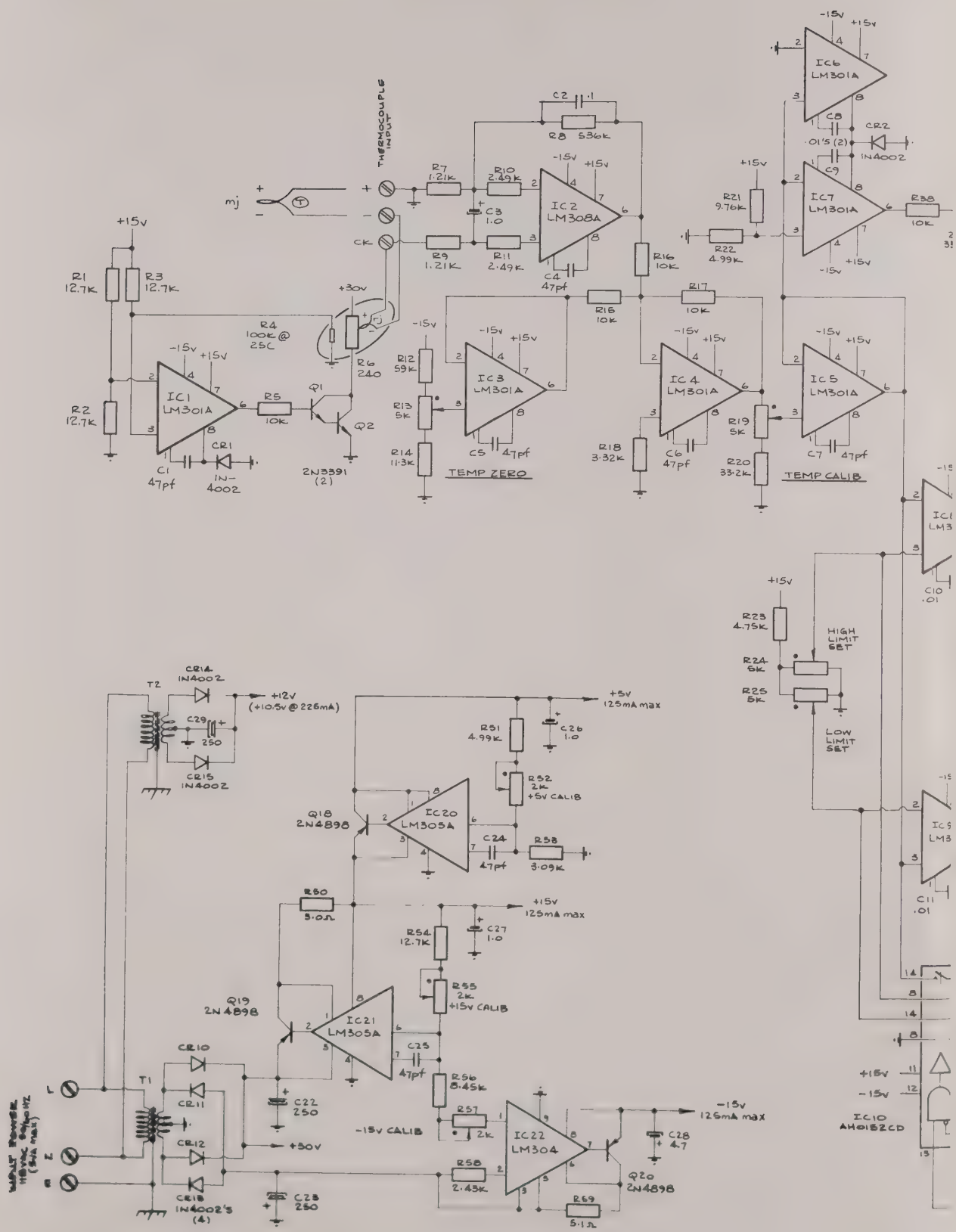
NOTE: As previously stated in this manual, we do not recommend that you stock these items since, in practice, it is very difficult to predict what types of failures might occur. However, when special circumstances warrant it, we suggest that the above items are the most likely choice of parts to keep on hand.

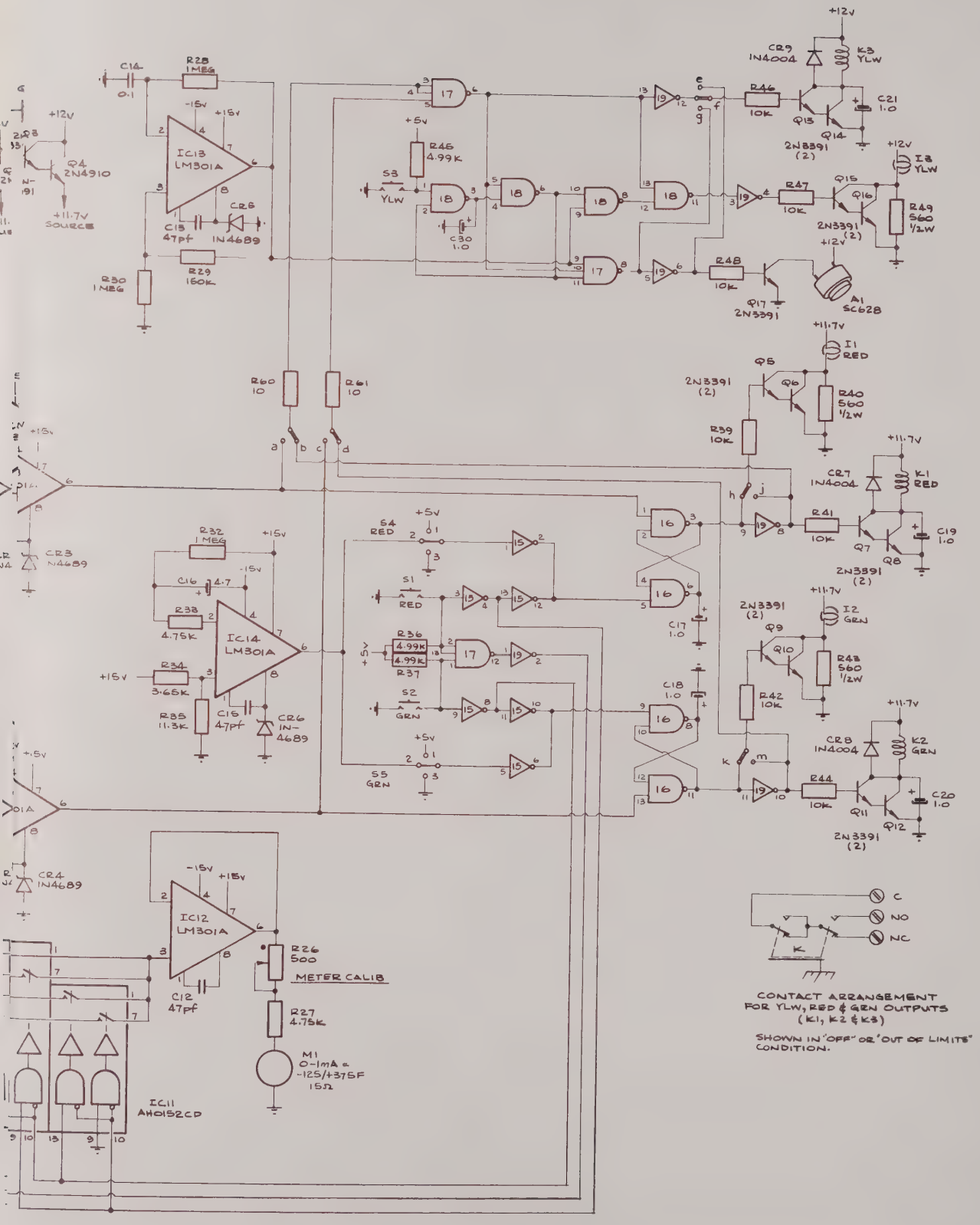
191007	AWG 20	Blk	12"	Term PCB L to Pwr PCB L
191008		Wht	12"	Term PCB N to Pwr PCB N
191009		Grn	12"	Term PCB E to Pwr PCB E
191010	AWG 22	Wht	7.5"	M1+to Main PCB R27
191011		Brn	11.4"	A1–to Main PCB Q17
191012		Red	7.3"	I1–to Main PCB Q6
191013		Org	7.4"	R24w on S.P. PCB to Main PCB IC8-3
191014		Ylw	7.7"	I3–to Main PCB Q16
191015		Grn	7.1"	I2–to Main PCB Q10
191016		Lt Blu	12.0"	Term PCB CK to Main PCB R9
191017		Vlt	3.7"	I3+ to A1+
			10.0"	K3+ to Term PCB to Pwr PCB +12v [H]
			12"	I3+ to Pwr PCB +12v [K]
191018		Blk	2.0"	S2– to S3–
			2.0"	S3– to S1–
			7.6"	M1– to Main PCB gnd [by Q17]
			9.0"	S.P. PCB gnd to Main PCB gnd [by R61]
			12.0"	S1– to Pwr PCB gnd [A]
			9.3"	Pwr PCB gnd [B] to Main PCB R7 [by Q2]
			9.3"	Pwr PCB gnd [A] to Main PCB gnd [by Q6]
191019		Gry	8.4"	Main PCB IC7-6 to Pwr PCB R38 [P]
191020		Blu	7.2"	R25w on S.P. PCB to Main PCB IC9-2
191022		Wht/Red	5.6"	S1+ to Main PCB IC15-3
191023		Wht/Grn	5.6"	S2+ to Main PCB IC15-9
191024		Wht/Ylw	5.6"	S3+ to Main PCB IC18-1 [by R45]
191025		Wht/Blu	12.0"	Term PCB + to Main PCB R7
191028		Wht/Vlt	2.0"	I1+ to I2+
			9.0"	I1+ to Pwr PCB Q4 [J]
			11.0"	K1+ on Term PCB to Pwr PCB Q4 [H]
191029		Wht/Blk/Blu	6.0"	Pwr PCB –15v [D] to Main PCB –15v [by R19]
191030		Wht/Blk/Brn	6.0"	Pwr PCB +5v [G] to Main PCB +5v [by IC16]
191031		Wht/Blk/Org	5.6"	Pwr PCB +15v [F] to Main PCB +15v [by CR3]
			6.0"	Pwr PCB +15v [F] to S.P. PCB +15v
191032		Wht/Blk/Red	10.0"	Term PCB K1– to Main PCB Q8
191033		Wht/Blk/Grn	10.0"	Term PCB K2– to Main PCB Q12
191034		Wht/Blk/Ylw	11.0"	Term PCB K3– to Main PCB Q14
191035		Wht/Blk/Vlt	10.5"	Pwr PCB +30v [C] to Main PCB RJC

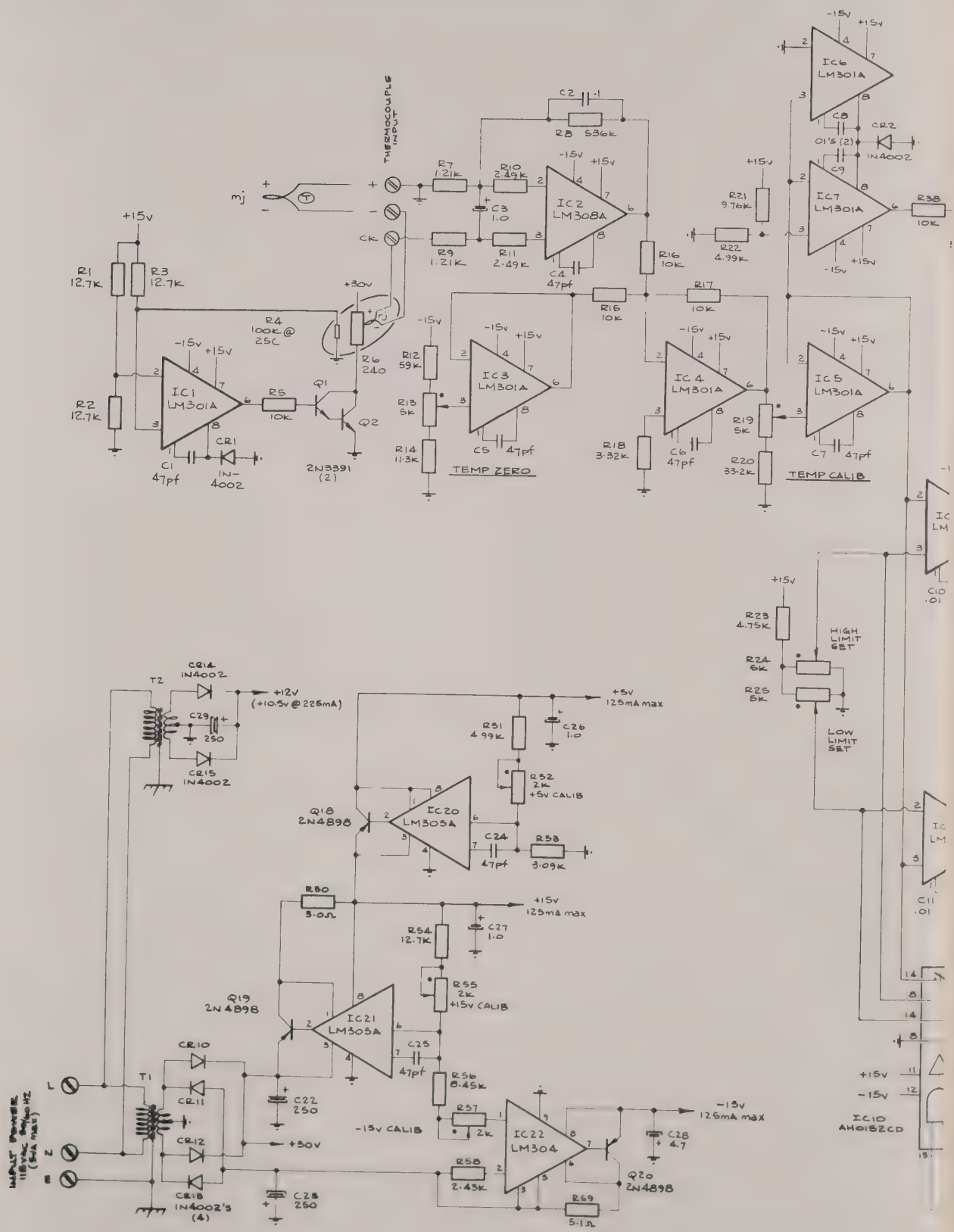

+12v
CR9 IN4004
K3 YLW
C21 1.0
R46 10K
Q13
Q14
2N3391 (2)
I3 YLW
R47 10K
Q15
Q16
R49 560 1/2W
R48 10K
Q17 2N3391
A1 SC628
+11.7v
I1 RED
Q5
Q6
2N3391 (2)
R40 560 1/2W
R39 10K
CR7 IN4004
K1 RED
R41 10K
Q7
Q8
C19 1.0
2N3391 (2)
I2 GRN
Q9
Q10
R43 560 1/2W
R42 10K
CR8 IN4004
K2 GRN
R44 10K
Q11
Q12
C20 1.0
2N3391 (2)
C14 0.1
R28 1MEG
IC13 LM301A
-15v
+15v
CR8
C13 47pf
IN4689
R29 150K
R30 1MEG
Q4 2N4910
R60 10
R61 10
+5v
R45 4.99K
S3 YLW
C30 1.0
R32 1MEG
IC14 LM301A
C16 4.7
R33 4.75K
R34 3.65K
R35 11.3K
C16 47pf
CR6 IN4689
S4 RED
S1 RED
R36 4.99K
4.99K
R37
S2 GRN
S5 GRN
C17 1.0
C18 1.0
IC12 LM301A
R26 500
METER CALIB
R27 4.75K
M1 0-1mA = -125/+375F 150Ω
C12 47pf
IC11 AH0152CD
C
NO
NC
K
CONTACT ARRANGEMENT FOR YLW, RED & GRN OUTPUTS (K1, K2 & K3)
SHOWN IN "OFF" OR "OUT OF LIMITS" CONDITION.

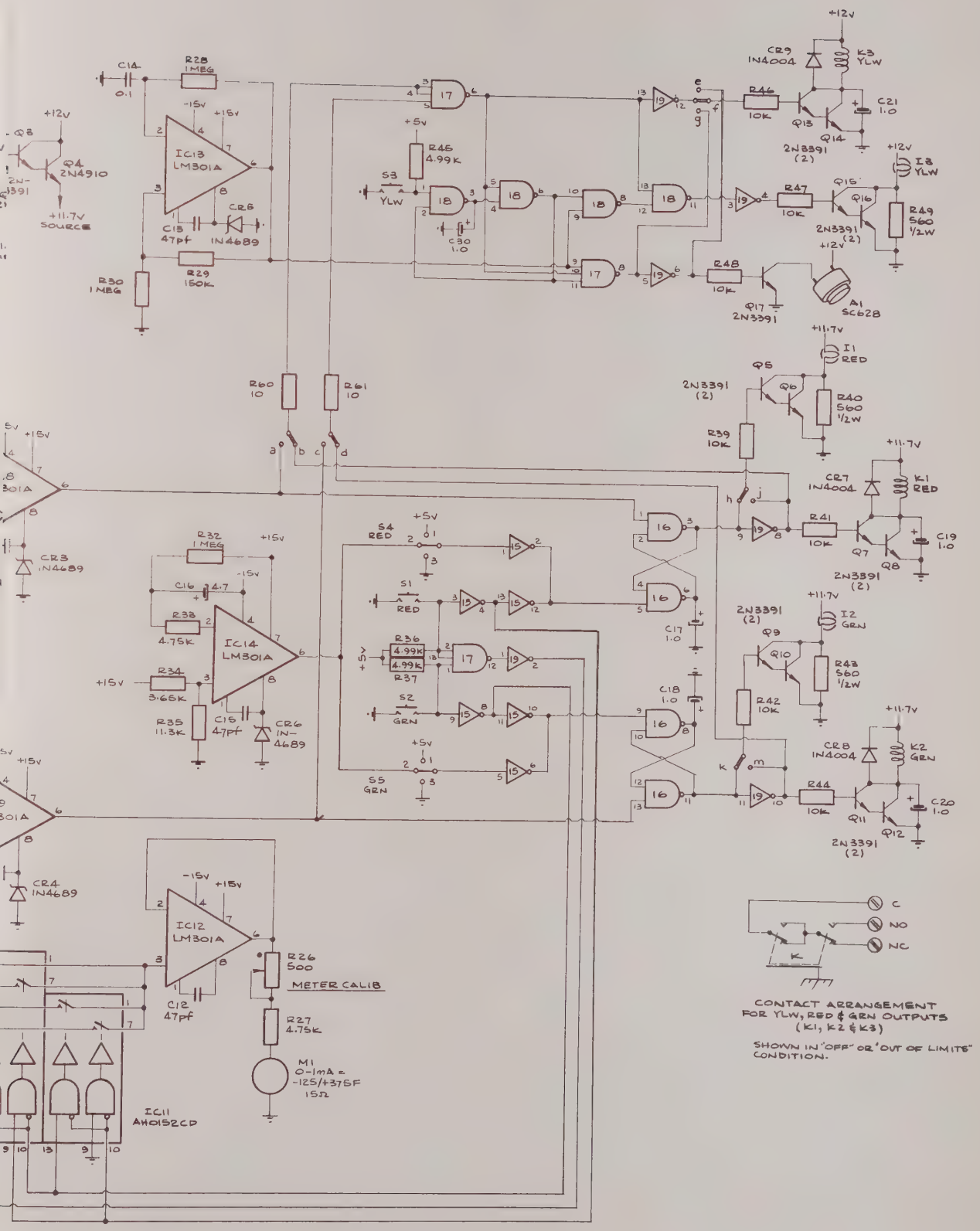

THERMOCOUPLE INPUT
mj
CK
+15v
-15v
R1 12.7K
R2 12.7K
R3 12.7K
R4 100K @ 25C
R5 10K
R6 240
+30v
Q1
Q2
2N3391 (2)
IC1 LM301A
C1 47pf
CR1 IN-4002
R7 1.21K
R9 1.21K
R10 2.49K
R11 2.49K
C2 .1
R8 536K
C3 1.0
IC2 LM308A
C4 47pf
R16 10K
R17 10K
R18 3.32K
R19 5K
R20 33.2K
IC3 LM301A
IC4 LM301A
IC5 LM301A
R12 59K
R13 5K
R14 11.3K
C5 47pf
C6 47pf
C7 47pf
TEMP ZERO
TEMP CALIB
IC6 LM301A
IC7 LM301A
C8 .01's (2)
C9
CR2 IN4002
R21 9.76K
R22 4.99K
R23 10K
IC10 AH0152CD
C10 .01
C11 .01
R23 4.75K
R24 6K
R25 5K
HIGH LIMIT SET
LOW LIMIT SET
INPUT POWER 115VAC 60Hz (5VA max)
L
N
E
T1
T2
CR10
CR11
CR12
CR13 IN4002's (4)
CR14 IN4002
CR15 IN4002
C29 250
+12v (+10.5v @ 225mA)
C22 250
C28 250
+50v
-15v CALIB
R51 4.99K
C26 1.0
+5v 125mA max
R52 2K +5v CALIB
Q18 2N4898
IC20 LM305A
C24 47pf
R58 3.09K
R60 3.0Ω
+15v 125mA max
R54 12.7K
C27 1.0
R55 2K +15v CALIB
Q19 2N4898
IC21 LM305A
C25 47pf
R56 8.45K
R57 2K
IC22 LM304
C28 4.7
R58 2.45K
R59 5.1Ω
Q20 2N4898
-15v 125mA max


+12V
CR9 IN4004
K3 YLW
C21 1.0
R46 10K
Q13
Q14
2N3391 (2)
I3 YLW
Q15
Q16
R49 560 1/2W
R47 10K
R48 10K
Q17 2N3391
A1 SC628
+11.7V
I1 RED
Q5
Q6
2N3391 (2)
R40 560 1/2W
R39 10K
CR7 IN4004
K1 RED
R41 10K
Q7
Q8
C19 1.0
I2 GRN
Q9
Q10
R43 560 1/2W
R42 10K
CR8 IN4004
K2 GRN
R44 10K
Q11
Q12
C20 1.0
C14 0.1
R28 1MEG
IC13 LM301A
C15 47pf
CR5 IN4689
R29 150K
R30 1MEG
Q3 2N-3391
Q4 2N4910
+11.7V SOURCE
R45 4.99K
S3 YLW
C30 1.0
R60 10
R61 10
S4 RED
S1 RED
S2 GRN
S5 GRN
R36 4.99K
R37 4.99K
C17 1.0
C18 1.0
R32 1 MEG
C16 4.7
R33 4.75K
IC14 LM301A
R34 3.65K
R35 11.3K
C16 47pf
CR6 IN-4689
CR3 IN4689
CR4 IN4689
IC12 LM301A
R26 500
METER CALIB
R27 4.75K
C12 47pf
M1 0-1mA = -125/+375F 150Ω
IC11 AH0152CD
C
NO
NC
K
CONTACT ARRANGEMENT FOR YLW, RED & GRN OUTPUTS (K1, K2 & K3)
SHOWN IN "OFF" OR "OUT OF LIMITS" CONDITION.


THERMOCOUPLE INPUT
+15v
-15v
IC1 LM301A
IC2 LM308A
IC3 LM301A
IC4 LM301A
IC5 LM301A
IC6 LM301A
IC7 LM301A
IC20 LM305A
IC21 LM305A
IC22 LM304
IC10 AH0182CD
Q1
Q2
2N3391 (2)
Q18 2N4898
Q19 2N4898
Q20 2N4898
R1 12.7K
R2 12.7K
R3 12.7K
R4 100K@ 25C
R5 10K
R6 240
R7 1.21K
R8 536K
R9 1.21K
R10 2.49K
R11 2.49K
R12 59K
R13 5K
R14 11.3K
R16 10K
R17 10K
R18 3.32K
R19 5K
R20 33.2K
R21 9.76K
R22 4.99K
R23 4.75K
R24 5K
R25 5K
R38 10K
R50 5.0Ω
R51 4.99K
R52 2K +5v CALIB
R54 12.7K
R55 2K +15v CALIB
R56 8.45K
R57 2K -15v CALIB
R58 2.43K
R69 5.1Ω
C1 47pf
C2 .1
C3 1.0
C4 47pf
C5 47pf
C6 47pf
C7 47pf
C8 .01's (2)
C9
C10 .01
C11 .01
C22 250
C23 250
C24 47pf
C25 47pf
C26 1.0
C27 1.0
C28 4.7
C29 250
CR1 IN-4002
CR2 IN4002
CR10
CR11
CR12
CR13 IN4002's (4)
CR14 IN4002
CR15 IN4002
T1
T2
TEMP ZERO
TEMP CALIB
HIGH LIMIT SET
LOW LIMIT SET
+12V (+10.5v @ 226mA)
+5v 125mA max
+15v 125mA max
-15v 126mA max
+30v
-15v CALIB
INPUT POWER 115VAC 60cycle/Hz (25VA max)


+12V
CR9 IN4004
K3 YLW
C21 1.0
R46 10K
Q13
Q14
2N3391 (2)
I3 YLW
Q15
Q16
R49 560 1/2W
R47 10K
2N3391 (2)
R48 10K
Q17 2N3391
A1 SC628
+11.7V
I1 RED
Q5
Q6
2N3391 (2)
R40 560 1/2W
R39 10K
CR7 IN4004
K1 RED
C19 1.0
R41 10K
Q7
Q8
2N3391 (2)
I2 GRN
Q9
Q10
R43 560 1/2W
R42 10K
CR8 IN4004
K2 GRN
C20 1.0
R44 10K
Q11
Q12
2N3391 (2)
C1A 0.1
R28 1MEG
IC13 LM301A
-15V
+15V
CR5 IN4689
C13 47pf
R29 150K
R30 1MEG
Q4 2N4910
+11.7V SOURCE
R45 4.99K
S3 YLW
C30 1.0
R60 10
R61 10
a b c d
e f g h j k m
S4 RED
S1 RED
S2 GRN
S5 GRN
R36 4.99K
R37 4.99K
C17 1.0
C18 1.0
R32 1MEG
C16 4.7
R38 4.75K
IC14 LM301A
R34 3.65K
R35 11.3K
C15 47pf
CR6 IN4689
CR3 IN4689
CR4 IN4689
IC12 LM301A
R26 500
METER CALIB
R27 4.75K
C12 47pf
M1 0-1mA ≈ -125/+375F 15Ω
IC11 AH0152CD
C NO NC
CONTACT ARRANGEMENT FOR YLW, RED & GRN OUTPUTS (K1, K2 & K3)
SHOWN IN "OFF" OR "OUT OF LIMITS" CONDITION.


THERMOCOUPLE INPUT
mj
+15v
-15v
R1 12.7K
R3 12.7K
R2 12.7K
R4 100K @ 25C
R6 240
+30v
IC1 LM301A
R5 10K
Q1
Q2
2N3391 (2)
C1 47pf
CR1 IN-4002
R7 1.21K
R9 1.21K
R10 2.49K
R11 2.49K
C3 1.0
IC2 LM308A
C4 47pf
C2 .1
R8 536K
R16 10K
R17 10K
R12 59K
R13 5K
R14 11.3K
IC3 LM301A
C5 47pf
TEMP ZERO
IC4 LM301A
C6 47pf
R18 3.32K
R19 5K
R20 33.2K
IC5 LM301A
C7 47pf
TEMP CALIB
IC6 LM301A
C8 01's (2)
CR2 IN4002
R21 9.76K
R22 4.99K
IC7 LM301A
C9
R38 10K
IC10 AH0152CD
IC LM
C10 .01
C11 .01
R23 4.75K
R24 6K
R25 5K
HIGH LIMIT SET
LOW LIMIT SET
CR14 IN4002
T2
+12v (+10.5v @ 226mA)
C29 250
CR15 IN4002
+5v 125mA max
R51 4.99K
C26 1.0
R52 2K +5v CALIB
Q18 2N4898
IC20 LM305A
C24 47pf
R58 3.09K
R60 3.0Ω
+15v 125mA max
R54 12.7K
C27 1.0
R55 2K +15v CALIB
Q19 2N4898
IC21 LM305A
C25 47pf
R56 8.45K
CR10
CR11
CR12
CR13 IN4002's (4)
T1
INPUT POWER 115VAC 50/60 HZ (5A max)
L
N
E
C22 250
C23 250
+50v
-15v CALIB
R57 2K
IC22 LM304
C28 4.7
R59 2.43K
R69 5.1Ω
Q20 2N4898
-15v 126mA max


+12V
CR9 IN4004
K3 YLW
R46 10K
C21 1.0
Q13
Q14
2N3391 (2)
I3 YLW
R47 10K
Q15
Q16
R49 560 1/2W
2N3391 (2)
R48 10K
Q17 2N3391
A1 SC628
+11.7V
I1 RED
Q5
Q6
2N3391 (2)
R40 560 1/2W
R39 10K
CR7 IN4004
K1 RED
R41 10K
Q7
Q8
C19 1.0
2N3391 (2)
+11.7V
I2 GRN
Q9
Q10
R43 560 1/2W
R42 10K
CR8 IN4004
K2 GRN
R44 10K
Q11
Q12
C20 1.0
2N3391 (2)
C1A 0.1
R28 1MEG
IC13 LM301A
-15V
+15V
CR5 IN4689
C13 47pf
R29 150K
R30 1MEG
+5V
R45 4.99K
S3 YLW
C30 1.0
R60 10
R61 10
a b c d
S4 RED
S1 RED
R36 4.99K
R37 4.99K
S2 GRN
S5 GRN
C17 1.0
C18 1.0
R32 1MEG
C16 4.7
R33 4.75K
IC14 LM301A
R34 3.65K
R35 11.3K
C15 47pf
CR6 IN4689
CR3 IN4689
CR4 IN4689
IC12 LM301A
R26 500
METER CALIB
C12 47pf
R27 4.75K
M1 0-1mA = -125/+375F 150Ω
IC11 AH0152CD
C
NO
NC
K
CONTACT ARRANGEMENT FOR YLW, RED & GRN OUTPUTS (K1, K2 & K3)
SHOWN IN "OFF" OR "OUT OF LIMITS" CONDITION.

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